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# JOURNAL

OF THE

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INCLUDING

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AND

GEO. E. PREECE, Secretary.

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| A. | Naylor, J. E. | Postal Telegraphs, York. |
| A. | Ollard, J. F. | Lloyd's, Royal Exchange, E.C. |
| A. | Ormiston, Frederick Aldridge | Postal Telegraphs, Telegraph St., E.C. |
| F.M. | Orton, Hon. William | 145, Broadway, New York. |

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|---|---|---|
| M. | Phillips, Samuel E. | 20, Francis Terrace, Victoria Park, Hackney, N.E. |
| M. | Phillips, Samuel E., Junior | Fern Cottage, Upper Whitworth Road, Plumstead. |
| M. | Preece, G. E. | 5, Maitland Park Road, Haverstock Hill, N.W |
| M. | Preece, W. H., C.E. | Grosvenor House, Southampton. |
| M. | Pepper, J. H., Professor | 209, Regent Street, W. |
| A. | Petersen, K. | 7, Great Winchester Street Buildings, E.C. |
| A. | Pinchin, William Henry | Postal Telegraphs, Exeter. |
| A. | Partridge, G. Noble | Postal Telegraphs, Exeter. |
| F. M. | Preece, John Richard | Ispahan, Persia, Indo-European Telegraphs. |
| F. M. | Possmann, J. | Indo-European Telegraph Department, Persian Gulf. |
| S. | Palliser, Edward | Care of Major Bolton, 2, Westminster Chambers, S.W. |
| F. M. | Pope, Frank, L. | 80, Broadway, New York. |
| M. | Radcliffe, James | G. N. Railway, Retford. |
| M. | Reuter, Baron de | Kensington Palace Gardens. |
| M. | Ricketts, F. H. | 3, Great George Street, Westminster, S.W. |
| M. | Robinson, D., Lieut.-Col., R.E. | Rectory, Battle, Hastings. |
| M. | Rokeby, Langham, Capt. | Care of Francis Parry, 102, Piccadilly, W. |
| A. | Ramsay, John, Lieut. R.N. | Chatham. |
| A. | Ritso, F. C. G. | 7, Lothbury, E.C. |
| A. | Russell, Frank | 44, Finsbury Circus, E.C. |
| M. | Ronalds, Sir Francis, F.R.S | Battle, Sussex. |
| A. | Risch, Gustav | 9, Armstrong Terrace, New Charlton, S.E. |
| A. | Rolls, Edward T. | L. & S. W. Railway, Southampton. |
| A. | Radcliffe, Arthur | 101, New Street, Birmingham. |
| A. | Robertson, J. | Postal Telegraphs, Bristol. |
| A. | Richardson, H. | Postal Telegraphs, Douglas, Isle of Man. |
| A. | Reid, Frank | Postal Telegraphs, Newcastle-on-Tyne |
| F. M. | Reynolds, Charles | Calcutta, India. |
| M. | SABINE, ROBERT, C.E. | 3, Delahay Street, Westminster, S.W. |
| M. | Sach, H. | G. E. Railway, Shoreditch Station, E. |
| M. | Schwendler, L., C.E. | Electric Superintendent Government Telegraphs, Calcutta, India. |

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| M. | Scott, R. G., Lieutenant R.E. . . | Chatham. |
| M. | SCUDAMORE, FRANK IVES, C.B. | General Post Office,, St. Martin's-le-Grand, E.C. |
| M. | Shaw, W. H. . . . . | Post Office Telegraphs, N. E. Division, Newark, Notts. |
| M. | Siemens, Carl . . . . . | 3, Great George Street, Westminster, S.W. |
| M. | SIEMENS, CHARLES WILLIAM F.R.S., D.C.L. | 3, Great George Street, Westminster, S.W. |
| M. | Silver, S. W. . . . . | 67, Cornhill, E.C. |
| M. | Smith, Theophilus . . . . | 6, Merrick Square, Borough, S.E. |
| M. | SMITH, WILLOUGHBY . . | 18, Wharf Road, City Road, N. |
| M. | Spagnoletti, C. E. . . . . | G. W. Railway, Paddington, W. |
| M. | STOTHERD, MAJOR, R.H., R.E. . | Brompton Barracks, Chatham. |
| A. | Smith, Toulmin . . . . . | 3, Gt. George Street, Westminster, S.W. |
| A. | Schramm, Otto . . . . . | 3, Gt. George Street, Westminster, S.W. |
| M. | Stockley, Capt., R.N. . . . | Chatham. |
| M. | Sanger, Thomas Henry . . . | Postal Telegraphs, Dublin. |
| A. | Stokes, John Scott . . . . | Postal Telegraphs, Southampton. |
| A. | Sivewright, James . . . . | Postal Telegraphs, Southampt on. |
| A. | Spagnoletti, Hylton . . . . | 4, Circus Street, Marylebone, W. |
| A. | Siemens, Alexander . . . . | 3, Gt. George Street, Westminster, S.W. |
| F.M. | Siemens, Dr. Werner . . . . | Berlin. |
| A. | Smith, J. H. . . . . | Care of Major Bolton, 2, Westminster Chambers, S.W. |
| A. | Shaw, John . . . . . | Postal Telegraphs, Bolton. |
| M. | Sprot, J. Lieut.-Col. . . . . | Junior United Service Club, Waterloo Place. |
| M. | Saunders, John Brewer . . . | The Laurels, Taunton. |
| A. | Stevenson, Ed. Alf. . . . . | Telegraph Construction and Maintenance Company, Enderby's Wharf, East Greenwich, S.E. |
| A. | Symington, Robert Stevenson . . | Postal Telegraphs, Glasgow. |
| M. | Simmons, Sir Linton, Major-Gen., K.C.B. | Royal Military Academy, Woolwich. |
| A. | Sax, J. . . . . | 103, Great Russell Street, W.C. |
| A. | Saunders, H. . . . . | British Indian Submarine Telegraph Company, 66, Old Broad Street. |
| F.M. | Sauty, C. V. de . . . . . | F. G. & M. Telegraph Company, Gibraltar. |
| M. | Taylor, Herbert . . . . . | The Avenue, Gipsy Hill, S.E. |
| M. | Ternant, A. L. . . . . | Algiers and Malta Telegraph Co., Marseilles, France. |
| M. | Thomson, Sir William, F.R.S., LL.D. | The University, Glasgow, N.B. |
| M. | *Tyndall, John, Professor, LL.D., F.R.S. | Royal Institution, Albemarle St., W. |

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| A. | Theiler, M. . . . . | 156, Barnsbury Road, N. |
| F.M. | Tietgen, C. F. . . . . | Great Northern Telegraph Company, Copenhagen. |
| A. | Taylor, William Grigor . . . | Telegraph Construction Company, Morden Wharf, East Greenwich. |
| A. | Tubb, Albert . . . . . | Postal Telegraphs, Southampton. |
| A. | Tolmé, Julian H. . . . . | 1, Victoria Street, Westminster, S.W. |
| A. | Treuenfeld, Von, Fischer . . . | 277, Vauxhall Bridge Road, S.W. |
| M. | Tansley, Ed. . . . . | Postal Telegraphs, Edinburgh. |
| M. | Todd, Lieut. R.E. . . . . | Brompton Barracks, Chatham. |
| M. | VARLEY, C.F., F.R.S. . . . | 1, Great Winchester Street Buildings, Old Broad Street, E.C. |
| M. | Varley, F. H. . . . . | Mildmay Park Works, Stoke Newington, N. |
| M. | Varley, Octavius . . . . | Mildmay Park Works, Stoke Newington, N. |
| M. | Varley, S. A. . . . . | 66, Roman Road, Holloway, N. |
| M. | Von Chauvin, George . . . | 3, Gt. George Street, Westminster, S.W. |
| M. | Walker, C. V., F.R.S. . . . | Fern Side, Red Hill, Reigate. |
| M. | Warren, T. T. P. B. . . . | Tamworth House, Mitcham, Surrey |
| M. | Webb, F. C., C.E. . . . . | 57, Maitland Park Road, N.W. |
| M. | WEBBER, C. EDMOND, CAPT., R.E. | Postal Telegraph, Fountain Court, Liverpool Street, E.C. |
| M. | Wheatstone, Sir Charles, D.C.L., F.R.S. | 19, Park Crescent, Portland Place, N.W. |
| M. | WHITEHOUSE, E. O. WILDMAN | Pilgrim Lane, Hampstead, N.W. |
| M. | Weaver, Henry . . . . . | 1, Albert Square, Clapham Road, S.W. |
| M. | Walsh, John . . . . . | Postal Telegraph Department, Manchester. |
| M. | Winter, William Henry . . . | Postal Telegraph Department, 28, Coleman Street, E.C. |
| A. | Willmot, Joseph . . . . | Postal Telegraphs, Telegraph St., E.C. |
| A. | Winter, Charles . . . . . | Postal Telegraphs, Guernsey. |
| M. | Williamson, Prof. . . . . | University College, Gower Street, W.C. |
| A. | Watson, C., Lieut. R.E. . . . | Chatham. |
| A. | Walton, John . . . . | Postal Telegraphs, Cardiff. |
| A. | Watkins, Lieut. R.E. . . | Aldershot. |
| A. | Werdermann, E. H. . . . . | 4, Princes Street, Stamford Street, Southwark, S.E. |
| M. | Wilson, H. Schütz. . . . . | 185, Regent Street, W. |
| A. | Woollen, C.H. . . . . | Postal Telegraphs, Exeter. |
| M. | Walker, E. J. Douglas . . . | 19, Adam Street, Adelphi, W.C. |

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# RULES AND REGULATIONS.

## OBJECTS.

The SOCIETY OF TELEGRAPH ENGINEERS is established for the general advancement of Electrical and Telegraphic Science, and more particularly for facilitating the exchange of information and ideas among its Members.

## CONSTITUTION.

1. THE SOCIETY OF TELEGRAPH ENGINEERS shall consist of Members, Associates, Students, Foreign Members, and Honorary Members.

2. MEMBERS.—Every Member shall have been previously elected as an Associate of the Society, and shall come within one of the following conditions:—

(*a.*) He shall have been regularly educated as a Telegraph Engineer, according to the usual routine of pupilage, and have had subsequent employment for at least five years in responsible situations.

(*b.*) Or he shall have practised on his own account in the profession of a Telegraph Engineer for at least two years, and have acquired a degree of eminence in the same.

(*c.*) Or he shall be so intimately associated with the science of Electricity or the progress of Telegraphy that the Council consider his admission to Membership would conduce to the interests of the Society.

3. ASSOCIATES shall be of more than twenty-one years of age, and this class shall include persons whose pursuits constitute branches of Electrical Engineering, who are not necessarily Telegraph Engineers by profession, but who are, by their connection with Science, qualified to concur with Telegraph Engineers in the advancement of professional knowledge.

4. STUDENTS shall be persons not under eighteen and not over twenty-one years of age, who are serving pupilage to a Telegraph Engineer, or who are studying Natural Science, and are duly recommended by a Member.

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5. HONORARY MEMBERS shall be either distinguished individuals who from their position are enabled to render assistance in the prosecution of Telegraphic enterprises, or persons eminent for science and experience in pursuits connected with the profession of Telegraphy, but who are not engaged in the practice of that profession. FOREIGN MEMBERS are also admitted, paying a subscription of £1 a year.

6. The OFFICERS of the Society shall be a *President*, two *Vice-Presidents*, and ten other *Members*, who shall constitute the *Council*, to direct and manage the affairs of the Society; also two Auditors of accounts, a Treasurer, an Honorary Secretary, and a Secretary. Such officers shall be elected or appointed annually in manner hereinafter directed.

7. In addition to the above. two Associates shall be elected annually to serve on the Council.

8. All the officers shall be elected from the class of Members.

9. These offices shall all be honorary, except that of Secretary.

## ELECTION AND EXPULSION OF MEMBERS, ASSOCIATES, AND OFFICERS.

10. Every applicant for admission into the Society shall be duly proposed and seconded in writing to the Secretary, who shall thereafter submit it to the Council, to be considered and brought by them before the following Meeting of the Society for approval.

11. HONORARY MEMBERS shall be elected by the Council, and notice thereof shall be given by the Secretary at the following meeting of the Society.

12. BALLOTS shall take place at the first Ordinary General Meeting of the Society in each year, and at each ensuing meeting during the Session. Members and Associates only have the right of voting.

13. The proportion of votes for deciding the election of any candidate shall be at least two-thirds of the numbers voting.

14. In any election, a second ballot shall be granted at the same Meeting, if it be demanded immediately by any three persons having a right to vote.

15. In case of the non-election of any person balloted for, no notice shall be taken thereof in the minutes.

16. The proposal for admission to the Society or for transferring any person from one class to another class shall be according to forms

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A or A 1 in the Appendix. These forms, being subscribed by at least ten Members, and delivered to the Secretary, shall be submitted to the Council for consideration.

17. Any person whose proposal has been passed by the Council shall be duly informed of it by a letter according to form B, containing an engagement to be signed by the candidate. After the ballot the Secretary shall inform the candidate thereof upon the form C.

18. In case the expulsion of any individual shall be judged expedient by ten or more Members or Associates, and they think fit to draw up and sign a proposal requiring such expulsion, the same, being delivered to the Secretary, shall be by him laid before the Council for consideration. If the Council, after due inquiry, do not find reason to concur in the proposal, no entry thereof shall be made in the minutes, nor shall any public discussion thereon be permitted; but, if the Council do find good reason for the proposed expulsion, they shall direct the Secretary to address a letter according to the form D in the Appendix to the person proposed to be expelled, advising him to withdraw from the Institution. If that advice be followed, no entry on the minutes, nor any public discussion on the subject, shall be permitted; but if that advice be not followed, nor a satisfactory explanation given, the Council shall call a Special General Meeting of Members and Associates for the purpose of deciding on the question of expulsion; and if a majority of the persons present at such Special General Meeting, provided the number so present be not less than twenty, vote that such individual be expelled, the Chairman of that Meeting shall declare the same accordingly, and the Secretary shall communicate the same to the individual according to the form E in the Appendix.

19. The President, Vice-Presidents, Treasurer, and Secretary shall be elected annually by ballot.

20. The President shall in no case hold that office for a longer period than one year; and at the expiration of such period he shall not be re-eligible for that office for the period of one year.

21. Three Members of the Council and the two Associate Members shall retire annually in rotation, and be ineligible for re-election during the following year.

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22. The Council shall, previous to the Annual Meeting in each year, prepare a list of Members whom they propose as suitable for the offices of President, Vice-President, Treasurer, and Honorary Secretary for the ensuing year. The list shall also contain the names of twelve Members and four Associates whom the Council nominate as fitted to become Members of the Council. A copy of such list to be forwarded to each Member of the Society before the Annual General Meeting, and each Member shall be at liberty to make a selection from the list, or to substitute the name or names of any other Member or Members for each respective office; but the number of names so selected or substituted must not in any case exceed the number to be elected to the respective offices.

## CONTRIBUTIONS OF MEMBERS AND ASSOCIATES TO THE SOCIETY.

23. Every Member shall contribute the sum of Two Guineas, every Associate the sum of one Guinea, every Foreign Member £1, and every Student Half a Guinea, annually, to the Society.

24. Honorary Members shall not be required to pay any contributions.

25. The annual contributions shall be payable in advance on the 1st of January in each year.

26. No Member, Associate, or Student whose contribution is six months in arrear shall be entitled to vote, nor to enter into any discussion, nor to receive the Society's printed papers.

27. Every individual admitted into the Society shall be considered as belonging thereto, and, as such, liable to the payment of his annual subscriptions until he has either forfeited his claim or has signified to the Secretary, in writing, his desire to resign, having previously paid all arrears.

28. Any Member may compound for his annual subscription by the payment, in one sum, of Twenty-five Guineas. All such compositions shall be invested in the names of three trustees, and the interest alone shall be appropriated to the current expenditure of the Society, at the direction of the Council.

## DUTIES OF THE COUNCIL.

29. The Council shall meet as often as the business of the Society may require; and at every meeting three shall constitute

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a quorum. The Council may appoint sub-committees, chosen from their own body, for special purposes, to report to the Council.

30. All questions shall be decided in the Council by vote; but at the desire, expressed in writing, of any two Members present, the determination of any subject shall be postponed to the succeeding Meeting of the Council.

31. A statement of the funds of the Society, and of the receipts and payments during the past year, shall be made under the direction of the Council, at the commencement of every Session, and after having been verified and signed by the Auditors, shall be laid before the first Meeting of the Session.

32. The Council shall draw up a yearly Report on the state of the Society, which shall be read at the same Meeting.

33. It shall be the duty of the Council to adopt every possible means for the advancement of the Society; to provide for properly conducting its business in all cases of emergency, such as the death or resignation of officers, &c.; and to arrange for the publication of the papers read at their Meetings, or of such documents as may be calculated to advance Electrical and Telegraphic knowledge, in such a way as they may deem advisable.

34. The Council, when they may consider it expedient to propose the enactment of any new regulation, or the alteration or repeal of any existing one, shall summon a General Meeting of Members to decide on the same; and the Council are at all times bound to do so on a requisition in writing of any ten Members, specifying the particular new regulation, or the alteration of an existing one, which they recommend.

## SESSIONS AND MEETINGS.

35. The Session of the Society shall commence on or about the 1st November of each year and terminate on or about the 1st June of the following year. During these months the Meetings of the Society will be held at the Society's Meeting Room, on evenings which the Council will appoint, and notice of which will be given to Members by the Secretary before the commencement of the Sessions.

36. The General Meetings of the Society shall be as follows:—1st. General Meetings of Members only, for the purpose of making, altering, and establishing Rules and Regulations.

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2nd. The Annual General Meeting. 3rd. Ordinary General Meetings. 4th. Special General Meetings.

37. A *soireé* of the Society will also be held during the Session.

38. The Annual General Meeting of the Society shall be held at the Meeting next previous to Christmas Eve, at eight o'clock in the evening, to receive and deliberate upon the Report of the Council on the state of the Society, and to elect the Officers for the ensuing year.

39. The Ordinary General Meetings shall be held during the Session, at eight o'clock in the evening. No new question shall be introduced, or motion be made, after ten o'clock.

40. The business of the Ordinary General Meetings of the Society shall be conducted as nearly as possible in the following order:

1. The Minutes of the preceding evening to be read and confirmed, and signed by the Chairman
2. Business arising out of the Minutes to be entered on.
3. Candidates for admission to be announced.
4. Any individual present for the first time since his election, having paid the usual contributions, and signed the Forms and the Register, to be introduced by the Chairman to the Meeting.
5. Presents to be announced and acknowledged.
6. Communications from the Council to be brought forward.
7. Minutes of Conversation of the last Meeting to be read and corrected, and any Abstracts, or portions of Papers to be read, if ordered by the Meeting.
8. New Communications to be read.
9. Questions for discussion to be brought forward.
10. Candidates for admission to be balloted for.

41. Every Member and Associate shall have the privilege of introducing one stranger, to be present at the Ordinary General Meetings of the Society, on writing his name in a book provided for that purpose, or sending with him a card signed with his name, according to a form provided.

42. No question shall be discussed, or motion be made, at the Ordinary General Meetings, relative to the direction and management

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of the concerns of the Society; such direction and management being vested in the Council.

43. A Special General Meeting of Members and Associates may be called at any time by the Council for a specific purpose relative to the direction and arrangement of the concerns of the Society, and the Council are at all times bound to do so on a requisition in writing of ten Members and Associates, specifying the nature of the business to be transacted. But such Special General Meeting shall have no power to make, alter, revoke, or dispense with any Rule whatsoever, such power being vested only in a General Meeting of Members.

44. Those Members and Associates who are resident within ten miles of the General Post Office shall have five days' notice of the time appointed by the Council for such Special General Meeting of Members and Associates; and the notices shall specify the nature of the business to be transacted, and no other than that business shall be transacted at that Meeting. All Members and Associates shall have a right to attend and vote.

# APPENDIX.

## A

A_____B_____ of_____
_____being desirous of admission into THE SOCIETY OF TELEGRAPH ENGINEERS, I recommend him, from personal knowledge, as a person in every respect worthy of that distinction.

[*Here specify distinctly the qualifications of the Candidate.*]

On the above grounds, I beg leave to propose him to the Council as a proper person to be admitted into the Society.

Signed, (C.D.) *Member.*

Dated this_____ day of_____18_____

We, the undersigned, concur in the above recommendation, being convinced that A.B. is in every respect a proper person to be admitted into the Society.

Signed,_____

The Council, having considered the above recommendation, present A.B. to be ballotted for as_____
of THE SOCIETY OF TELEGRAPH ENGINEERS.

Signed,_____
*Chairman.*

Dated_____day of_____18_____

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# A 1.

We, whose names are hereunto subscribed, submit to the Council of THE SOCIETY OF TELEGRAPH ENGINEERS the propriety of transferring A_____B_____ of_____from the class of _____in which he was elected to the class of _____because_____

[*Here specify distinctly the qualifications of the Candidate.*]

Witness our hands this_____day of_____18____.

The Council of THE SOCIETY OF TELEGRAPH ENGINEERS, meeting on the_____day of_____18____, transfer A. B. from the class of_____ to the class of_____

Signed,_____

*Chairman.*

# B.

*The Society of Telegraph Engineers.*

SIR,

I beg to inform you, that having been proposed by _____, and seconded by Messrs. _____, your name was laid before the Council and passed as_____of the Society, and was approved by the General Meeting on_____ Previously, however, to your proposal being submitted to Ballot at the Meeting of_____you are required to sign and return the accompanying engagement.

The result of the Ballot shall be communicated to you, with the formal documents, immediately after the Meeting.

I am, Sir, &c.

*The Society of Telegraph Engineers.*

I, the undersigned, being proposed for Ballot as_____of THE SOCIETY OF TELEGRAPH ENGINEERS, do hereby promise, that, in the event of my election, I will be governed by the Rules and Regulations of the said Society, as they are now formed, or as they may hereafter be altered, amended, or enlarged; and I promise to promote the objects of the said Society as far as shall be in my power, and to attend the meetings thereof as often as I conveniently can. Provided that whenever I shall signify in writing to the Secretary for the time being that I am desirous of withdrawing my name therefrom I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

I also engage to present to the Society an original communication, or some scientific work for the library, within the space of twelve months from the date of my election.

Witness my hand, this_____day of_____18____.

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## C.

*The Society of Telegraph Engineers.*

SIR,

I have the honour to inform you, that on the _____ day of _____ you were elected _____ of THE SOCIETY OF TELEGRAPH ENGINEERS, and I beg to transmit to you a copy of the Rules and Regulations of the Society.

According to the Regulations of the Society you are required as _____ to pay _____ being Subscription, to the Treasurer, within two months of the date of your election; otherwise your election will be void. This condition being complied with, you will be considered as admitted into the Society, and receive the diploma of your election; and any publications or notices to which you are entitled will be forwarded according to your directions.

I beg to direct your attention to Section 25 of the Rules, and to point out that all annual subscriptions become due on the 1st of January for the current year.

I am, Sir, &c.

## D.

*The Society of Telegraph Engineers.*

SIR,

I am directed by the Council of THE SOCIETY OF TELEGRAPH ENGINEERS to inform you that, upon mature consideration of a proposal which has been laid before them relative to you, they will call a Special General Meeting thereon, as is provided for by Section 15 of the Rules and Regulations of this Society. But previous to taking such a step it becomes the duty of the Council to advise you to withdraw from the Society, which can be done on your complying with Section 27.

I am, Sir, &c.

## E.

*The Society of Telegraph Engineers.*

SIR,

It is my duty to inform you that, by a Resolution of a Special General Meeting of Members and Associates of THE SOCIETY OF TELEGRAPH ENGINEERS, which was held here on the _____ day of _____ 18_____, according to the provisions of Section 15 of the Rules and Regulations, you were declared to be no longer belonging to the Society.

I am, Sir, &c.

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# THE SOCIETY OF TELEGRAPH ENGINEERS.

The First Ordinary General Meeting took place on Wednesday Evening, February 28th, 1872, in the large hall of the Institution of Civil Engineers, Mr. C. W. Siemens, D.C.L., F.R.S., President, in the Chair.

The President delivered an inaugural address, as follows:—

Gentlemen, in addressing you at this, the first General Meeting of the Society of Telegraph Engineers, I have, in the first place, to express to you my sincere thanks for the great honour you have bestowed upon me in electing me your President. It is not for me to question the wisdom of your choice, although I must confess that it took me completely by surprise; I must rather endeavour to justify your confidence in doing my best to promote the interests of the infant Society. Some years must necessarily elapse before our Society can have given substantial proof of its useful action, and by that time this chair will have been filled by other members of your body; but our future prosperity will be influenced in a great measure by the direction in which we shall start upon our pilgrimage. Let us hope, therefore, that our joint efforts may lead us in the direction of true scientific and practical advancement.

But before we set out upon our labours it behoves us fairly to consider whether there is need or scope for a Society of Telegraph Engineers? Is Telegraph Engineering not a branch of Civil Engineering, and do not all our proceedings therefore fall within the legitimate sphere of action of the Institution of Civil Engineers? Or if we meet with difficult questions in physical or mathematical science, is not the Royal Society or Section A of the British Association open for us to discuss them, or may we not go before the Institution of Mechanical Engineers with any purely mechanical question? Is it desirable, indeed, it may be urged, to take a branch from the parent stem and to cultivate it separately; shall we not degenerate thereby into "specialists," or what may be called "fractional quantities of scientific men," and this in the face of the patent fact that the further we advance in scientific knowledge (whether pure or applied) the more clearly we perceive the intimate connection between its different branches, and the impossibility of cultivating one without constantly reverting to the others.

In answer to such allegations we may fairly assert that we do n

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intend to become "specialists" in the narrow sense of wishing to confine the range of our knowledge to the phenomena and appliances which have an immediate application to our professional objects. We are, on the contrary, sensible to the fact that in order to master those *special* branches of knowledge thoroughly we shall have to travel into adjacent fields and build our practice upon the widest possible scientific foundation. But our time is limited, and, although the great principles of nature may be understood generally by one person, their applications are infinite, and all we may hope to do is to attain to a general scientific basis, and with it to devote our energies vigorously to the details of one or two branches of applied science.

If it is impossible for one man to master the special knowledge accumulated in different branches of Engineering Science, it would be equally impossible for one Society to cultivate all those branches in detail; thus the Royal Society can only entertain questions involving general principles of science, and is obliged to leave questions of exhaustive research to special societies; questions of minute chemical investigation are assigned to the Chemical Society; questions regarding the orbits of celestial bodies to the Astronomical Society; and by the same rule of limitation the Royal Society would refuse to receive, for instance, a paper on testing the joints of insulated wire, which would be a subject peculiarly suited for our Society. The Institution of Civil Engineers has, on the other hand, received, at certain intervals of time (varying from two to three years) a general paper on the progress of Telegraph Engineering; but it is self-evident that such an occasional paper must be quite inadequate to constitute a record of the progress of a branch of Engineering which gives daily proof of its public importance, which is distinguished for its rapid development, and which comprises within itself a wide range of scientific inquiry. Nor would there be time, on such rare occasions, to discuss questions of detail which are of special interest to the Telegraph Engineer.

We may, therefore, safely conclude that a Society of Telegraph Engineers is necessary for the more rapid development of a new and important branch of applied science; I further maintain that such an Institution is desirable in order to afford Telegraph Engineers frequent opportunities of meeting each other in friendly intercourse, and of impressing them with the conviction that their united action will be advantageous to the material interests of all.

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The *measure* of usefulness of the new Society must depend however, in the first place, upon its constitution and upon the amount of support which it is likely to receive, and in the second place upon the well-directed and continued exertions of its members, particularly of those members and associates who have accepted posts of trust in the Council, or as members of the Publishing Committee. As regards the constitution of the Society, a code of Rules has been prepared by the Committee appointed by the preliminary meeting of the original members, which have been placed in your hands. These Rules do not differ materially from those of other Societies having similar objects in view. The election of the President and Members of Council of the Society takes place annually, according to certain rules which have been framed with a view of combining efficiency of action with a gradual renewal from year to year of the governing body. The Society is open to all persons above 23 years of age, who are interested in Telegraphy without being necessarily Telegraph Engineers by profession—they may be physicists, engineers, administrators, or operators in the telegraphic service. They have to be proposed by several members or associates, and if the Council sees no grounds for disqualification, the candidate so proposed will be ballotted for at the first ordinary meeting of the Society. It is the duty of the Council to transfer those Associates who are duly qualified, according to the provisions of paragraph 2, into the class of members.

As regards accession of members, we have every reason to be satisfied with the first fruits of our labour. Our actual list of members contains already 110 names without counting the class of foreign members, regarding which I shall have to make a special communication and without counting the candidates for election, which you will be asked to admit by ballot this evening. I am happy to be able to point in our list of members to the historic names of Wheatstone, Cooke, and Morse, to the distinguished names of Thompson, Tyndall, and others scarcely less renowned for their important contributions to electrical science. Other well-known names will shortly appear in our next list of foreign and resident members. The support of the two great Telegraph Administrations of Great Britain and India is secured to us through the accession of the Directors-General and the Chief Engineers connected with those systems. The military branch of Telegraph Engineering is very fully represented by the distinguished chemist and engineer officers

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charged with those departments. As regards professional Telegraph Engineers the list includes an array of names many of which will ever remain associated with important improvements and generally with early telegraphic enterprize by sea and by land. The list of associate members includes names of promise and administrative ability, but it is as yet far too short for the well-being and the useful action of the Society. The aspirant Telegraph Engineer, the Superintendent of a Station, and others employed in the service, will find the Society of Telegraph Engineers, with its transactions, a useful source of technical information, and productive of excellent opportunities of meeting those who through personal acquaintance may forward their interests as well as extend their knowledge.

The Council have refrained from conferring honorary memberships, because they feel that the young Society has to establish its own worth before it can pretend to bestow such honorary distinctions which at a later period it is to be hoped men of high position will have pleasure in accepting.

On the other hand it is most desirable to secure for the young Society the support and co-operation of men occupying influential positions as directors and engineers of the great telegraphic systems of the world. The great network of international telegraphy extends already to every portion of the civilised and semi-civilised world; it traverses deserts and mountain chains, it passes over the deep plateau of the Atlantic and over the more dangerous bottom of tropical seas; what would be good practice in one country or under one order of climatic influences would be objectionable, insufficient, or wholly impracticable under another; but all these systems are intimately linked together, and the knowledge of the Telegraph Engineer must apply equally to all. In order however to combine the knowledge of these diverse circumstances, and of the diverse practice resulting therefrom, it is necessary for a Society of Telegraph Engineers to be a cosmopolitan institution, to be a focus into which the thoughts and observations of all countries flow, in order to be again radiated in every direction for the general advancement of this important branch of applied science.

In order to bring about such a result, the Council have agreed to the creation of another class of members,—"The Foreign Members,"—who, while receiving the transactions of the Society, and enjoying other privileges of membership, so far as distance will permit them

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to do so, will be called upon to pay only an annual subscription of 25 francs, or £1, instead of the £2 2s. payable by members residing in England. The Council authorised me to invite the representatives of the Telegraphic administrations of the world lately assembled in Congress at Rome to join our Society under this special title, and I am happy to state that my appeal has been most cordially responded to by the Directors-General and representatives of several of the most important Telegraphic systems of the Continent.

My application was conceived in the following terms:—

"MONSIEUR,

"J'ai l'honneur de vous addresser par la présente les Statuts de la "'Society of Telegraph Engineers,' de laquelle pour l'année courante j'ai été "élu de President, et qui s'est constituée dernièrement à Londres pour discuter "et pour publier régulièrement les progrès theoriques et pratiques qui seront "effectués de temps en temps dans le materiel télégraphique. Il est l'intention "du Comité de cette Société de donner un caractère international à ses trans-"actions, et de les publier avec tous les soins possibles. Elle cherche donc de "s'associer aux Directeurs aussi bien qu'aux Ingénieurs des systèmes télé-"graphiques continentales, et je suis chargé de vous prier de vouloir bien vous "associer à notre Société à titre de Membre étranger.

"Les Membres étrangers auront les mêmes droits que les Membres ordinaires "de la Société, ils recevront en outre toutes les transactions, et dans le cas "d'une participation suffisante il a été sugéré même de publier les transactions "en plusieurs langues. Le Comité de Publication sera heureux de recevoir les "communications que vous voudrez bien lui adresser pour être incorporées dans "les Transactions. La souscription annuelle pour les Membres étrangers a été "fixée à une livre sterling, au lieu de deux livres sterlings, et deux shillings la "souscription des Membres ordinaires.

"Les noms distingués qui se trouvent dans la liste de nos membres sera une "garantie suffisante, j'espère, pour vous satisfaire du caractère sérieux de cette "entreprise, dont le besoin s'est fait sentir vivement.

"En attendant votre considerération favorable, j'ai l'honneur d'être, "Monsieur, etc."

The following are among the answers which I have received:

### *From His Excellency General von Lüders, Director-General of the Imperial Russian Telegraphs.*

Rome, le 21 Décembre, 1871.

MONSIEUR,

En vous accusant reception des Statuts de la "Society of Telegraph Engineers," que vous avez en l'obligeance de me faire parvenir, je crois devoir vous exprimer ma vive reconnaissance pour l'invitation d'entrer à titre de Membre étranger dans la Société dont vous êtes le President, et je m'empresse de vous annoncer que j'accepte avec plaisir votre proposition.

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Parfaitement convaincu du caractère serieux et eminemment utile de l'entreprise organisée sous votre direction, je tacherai autant qu'il me sera possible de communiquer à la Société les renseignements qui pourront servir de matériel pour être incorporés dans les transactions que vous avez l'intention de publier.

Je vous prie, Monsieur, d'agréer l'assurance de ma considération très distinguée.

V. LÜDERS.

Mr. William Siemens,
President de la "Society of Telegraph Engineers."

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*From Sig. D'Amico, Director-General of Telegraphs in Italy.*

Rome, le 25 Décembre, 1871.

MONSIEUR,

Je suis très flatté de l'honneur d'appartenir comme Membre étranger à la Société des Ingénieurs télégraphiques, et je vous pemercie de la communication qui vous m'en avez faite par votre lettre de Rome récemment reçue.

J'ai pourtant disposé pour le payement au Trésorier de la Société à Londres, du montant en fcs. 25 de ma première souscription annuelle.

Agréez, Monsieur les expressions de ma parfaite estime.

Le Directeur Général
D'AMICO.

Monsieur Ch. William Siemens,
President de la "Société des Ingénieurs télégraphiques"
(Hotel Costanzi), Rome.

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*From Sig. Salvatori, Inspector-General of Telegraphs in Italy.*

Rome, 28 Décembre, 1871.

MONSIEUR,

C'est avec plaisir que j'accepte l'invitation que vous m'avez fait l'honneur de m'adresser, par votre lettre du 15 du mois courant, de me joindre, à titre de Membre étranger, à la "Society of Telegraph Engineers," dont vous avez bien voulu me communiquer les Statuts. Je vous prie, par conséquent, de me faire connaître à qui je devrai adresser le montant de la souscription annuelle et l époque du versement.

J'ai l'honneur d'être, Monsieur,
Votre très dévoué
F. SALVATORI.

Mr. W. Siemens, Hotel Costanzi, Rome.

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*From Mr. Ailhaud, the Representative of France.*

Rome, 25 Décembre, 1871.

MONSIEUR,

Je vous remercie de la communication que vous avez bien voulu m'adresser.

J'accepte avec reconnaissance la proposition que vous me faites, et j'ai l'honneur de vous prier de me compter au nombre des Membres étrangers de la "Society of Telegraph Engineers."

Je tiens à la disposition de la Société la somme de 25f. pour ma souscription annuelle.

Veuillez agréer, Monsieur, l'assurance de mes sentiments les plus distingués.

AILHAUD,
Inspecteur Général des Lignes télégraphiques, France.

Monsiéur William Siemens,
President de la "Society of Telegraph Engineers,"
Hotel Costanzi.

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*From M. Vinchant, the Representative of Belgium.*

Rome, Hotel de la Minerve, 17 Décembre, 1871.

MONSIEUR LE PRESIDENT,

En réference à la communication que vous avez bien voulu m'adresser au sujet de la "Society of Telegraph Engineers," j'ai l'honneur de vous informer que j'accepte avec empressement votre proposition de me joindre à cette Société, á titre de Membre étranger.

Veuillez agréer, Monsieur le Président, l'assurance de mes sentiments les plus distingués.

J. VINCHANT,
Inspecteur Général au Department des Travaux Publics de la Belgique.

Monsieur William Siemens,
Président de la "Society of Telegraph Engineers," Rome.

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*From the General Secretary of the International Bureau.*

Rome, le 20 Décembre, 1871.

MONSIEUR LE PRESIDENT,

J'accepte avec empressement l'offre que vouz avez bien voulu me faire d'être Membre étranger de la Société des Ingénieurs électriciens qui s'est constituée à Londres, et je vous serai reconnaissant de me faire connaître à qui je dois m'adresser pour faire parvenir le montant de ma contribution annuelle.

Veuillez agréer, Monsieur le Président, l'hommage de mes sentiments respectueux.

R. DE ST. MARTIAL.

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Rome, 17 Décembre, 1871.

MONSIEUR LE PRESIDENT,

J'ai pris connaissance avec intérêt de votre communication au sujet de la "Society of Telegraph Engineers" qui a été constituée dernièrement à Londres, et j'accepte volontiers l'offre que vous avez bien voulu avoir l'obligéance de me faire, d'être admis dans la société à titre de Membre étranger.

Veuillez agréer, Monsieur le Président, l'expression de mes sentiments distingués.

STARING,
Chef de la division des Telegraphes au Ministère des Finance des Pays Bas.

A Monsieur le Dr. C. William Siemens,
á Rome.

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Rome, 11 Janvier, 1872.

MONSIEUR,

En réponse à votre bien obligeante lettre m'invitant à me faire nscrire à titre de Membre Etranger dans la Société d'Ingénieurs Telegraphiques que vous si dignement dirigez, je m'empresse de vous faire connaître que j'accepte avec reconnaissance vôtre invitation, craignant seulement de n'être pas digne de l'honneur d'appartenir à une si illustre Corporation.

J'ai l'honneur d'etre, Monsieur,
Votre tres dévoué,
HIPPOLYTE ARANJO (Espagne).

Monsieur le Dr. C. William Siemens.

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Berlin, 20-2-72.

Auf Ihre freundliche Einladung zum Beitritt zu der neugebildeten Society of Tel. Engineers, d. d. Rom, den 31 Dec. 1871, erwiedere ich ergebenst, dass ich Ihrer Einladung mit Vergnügen Folge leiste und bitte mich als auswärtiges Mitglied der Gesellschaft aufzunehmen.

Hochachtungsvoll und ergebenst,
DR. WERNER SIEMENS.

An den Präsidenten der Society of Telegraph Engineers.
Herrn Dr. C. W. Siemens, London.

Other members of the conference have given their adhesion to our Society verbally. Professor Capanena, the Director-General of Brazilian Telegraphs, has also signified his intention to join as Foreign member. Mr. Lendi, the Director-General of the Swiss Telegraphs and chief of the Bureau International, and Professor Morse, our only but worthy representative of the United States of America, had already joined the Society, but will have to be transferred to the list of Foreign members, a privilege which may be claimed by all members (English or Foreign) residing permanently abroad.

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Our list of Foreign members will, it is to be hoped, include before long the names of many of the Inspectors-General and Engineers of the Telegraphic Government administrations of the Continent, several of the Directors-General having promised, if requested to do so, to exert their influence with the gentlemen of their staffs.

The idea of an International Society, or indeed of a practically useful Society of Telegraph Engineers, could not be realised without the publication of carefully edited transactions comprising not only the subject-matter of papers that may be brought before us from time to time, but of all matters of scientific or technical interest relative to Telegraphy that can be brought together.

Such transactions will be of great practical value to every Telegraph Engineer or Administrator, wherever he may be placed, being a reliable source of information for his guidance regarding authenticated progress in telegraphic science. Hereafter, they will form a valuable historic record. There is no lack of talent amongst our members for the accomplishment of so important an object, and it is to be hoped that the interest taken in the Society by its members will be sufficient for its accomplishment.

London is unquestionably the proper seat for such a Society, because it is the principal centre of the Telegraphic enterprise of the world, and musters consequently the greatest number of Telegraph Engineers. It is a remarkable fact that the manufacture of insulated wire, and of submarine cables, is almost entirely confined to the banks of the Thames. London also is very accessible, and is actually visited more than any other capital by the Engineers and the enterprising of all nations.

A serious difficulty in the way of giving to our proceedings an international character will arise, no doubt, through the diversity of languages dividing different nations. Many foreign engineers understand the English language, but others do not, and we could hardly expect their accession to our number unless we offered them our proceedings either in their own language, or at least in another language besides English, which they may understand. It may safely be assumed that every educated person throughout the civilised world speaks either French, German, or English, and it does not appear to me improbable that the time may come when we shall publish our proceedings in those three languages. The only condition necessary for such a course would be a sufficient accession of foreign members

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The expense of publishing a complete record of Telegraphic progress will certainly exceed the limits of our subscriptions, and it is proposed to establish a publishing fund, by voluntary donations and subscriptions, which it is hoped will be favourably received. We shall in this respect only follow the example set us by the Chemical Society, who have thus succeeded in producing the most valuable record of chemical progress.

History teaches us how to read the events of the present day and what we may reasonably look forward to even in the future; let us therefore review shortly in our minds the remarkable history of the Electric Telegraph, in order that we may be better prepared to deal with questions of immediate interest.

A generation has hardly passed away since the remarkable discoveries of Oerstead, Ampère, Faraday, and Weber, which laid the foundation of the electro-magnetic telegraph. The names of Steinheil, Schilling, Ronalds, Wheatstone, Cooke, and Morse, furnish us with striking illustrations of the readiness with which the thinking men of different nations turn scientific discovery to practical use. While these pioneers in the field of telegraphic progress were still contending against practical difficulties, other earnest labourers entered the same field, amongst whom Werner Siemens, Bain, and Brequet should not pass unmentioned here. But so rapid has been the progress of our branch of science, that, while I am obliged to speak of these men as belonging to our early history, they are still, almost without exception, living amongst us in full enjoyment of their faculties, and, I am happy to add, members of our new Society. They have the rare satisfaction to see their early day-dreams carried out upon so vast a scale that there is to-day hardly a country, however remote, that is not within a few minutes', or at all events a few hours' call from every central point of the civilised world, that diplomatic conferences have to be held to regulate international telegraphy, and that a proposal is seriously entertained by the leading powers of the earth to place telegraphic property upon the highest, I may also say a sacred basis, by declaring it inviolable in case of war. The electric telegraph has indeed attained to the dignity of a commercial, a social, and an international institution of the highest importance; it is a civiliser of the first magnitude, and we may well be proud to meet here together in furtherance of such a cause.

You will pardon me if I abstain from making special reference to the numerous claims to recognition of the fellow-labourers of the

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present day whom I am now addressing; they are well known within our own circle and to the public at large, but neither my ability nor the time at my command would suffice for such a task. I will only endeavour, before concluding this Address, to summarise the subject-matters which, judging from my experience, should engage our principal attention.

Problems of pure electrical science meet the telegraph engineer at every turn, the methods of testing insulated wire, of determining the position of a fault in a submarine cable under various circumstances, or of combining instruments so as to produce recorded messages by the mere fluctuation of electrical tension in a long submarine conductor, are problems worthy of the most profound physicist and mathematician. On the other hand, there is hardly a problem in electrical science that is not of practical interest to the Telegraph Engineer; and, considering that electricity is not represented at present by a separate learned society, ranking with the Chemical or Astronomical Societies, I am of opinion that we should not exclude from our subjects questions of purely electrical science. The phenomena of electrification and polarisation, of specific induction and conduction, the laws regulating the electrical wave, the influences of rise of temperature on conduction or the potential force residing in a coil of wire of a given form, when traversed by a current, involve questions belonging just as much to pure physical science as to the daily practice of the Telegraph Engineer, and would at any rate be inseparable from our proceedings. Next in order come questions of selection of materials for conduction or insulation, of apparatus for the best utilisation of feeble currents, of apparatus for producing, alternating, and directing electrical currents, which, although still intimately connected with physical science, call into play considerations of mechanical combinations. This brings us to questions of purely mechanical import, such as the mechanical construction of instruments for recording or printing messages, of protecting and supporting insulated conductors by sea or land, or of constructing machinery for the manufacture, the laying, and the repairing of submarine cables.

These questions again lead up to the more general ones of transport of materials through difficult and inhospitable countries, of navigation, of investigations into the depth and the nature of the bottom of seas, into the nature and effect of sea currents, and so forth, all of which belong, under certain aspects at least, to the province of the Telegraph Engineer.

I would go further, and include even statistical information respecting the nature and growth of telegraphic correspondence, without which it is impossible to adapt the construction of lines and of working instruments to the requirements of particular cases. The invention of a telegraphic instrument, for instance, is only of practical value if it is suited to the circumstances of the particular traffic for which it is intended, and to the electrical condition of the lines which it is proposed to work, and when the early pioneers of telegraphic progress elaborated ingenious instruments for sending and recording messages automatically or for printing them in Roman type, they invariably failed, because the then existing lines were insufficient in every way for such refinement, and the simple needle instrument seemed to suffice for all practical purposes. It was only when the exigencies of the traffic demanded a change, that instruments of this nature proved to be valuable inventions.

In like manner the long underground lines that were established on the Continent at an early date had to give way to suspended linewire, whereas the present practice and necessities undoubtedly tend toward a reversion to the former, as being less liable to interruption by accident or by atmospheric influences, and because an unlimited number of underground wires may be established between any two stations without encumbering the public thoroughfares. The best mode of insulating and protecting these underground wires with a view to reducing the inductive influence of the one upon the other, and of facilitating access to the one, for the purpose of repairs, without disturbing the others, are questions of practical interest for the present day.

The Electric Telegraph is applicable with the greatest positive advantage for the intercommunication between two points a great distance apart; through its agency New York and Calcutta are as near to us in point of time as are the suburbs of our metropolis from one another. It is probable, indeed, that in telegraphing from one suburb to another the message has to be oftener retransmitted than in going from the City of London to India or America, because a direct transmission from any one part of London to another would involve almost an infinite number of linewires in all directions. For this reason there must be a limit to the applicability of the Electric Telegraphs in populous districts, and it behoves us to examine whether another agent may not be preferable in dealing with a traffic of this description. The pneumatic tube seems to be well adapted to these

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circumstances, and having been first applied for short distances by Latimer Clark, and subsequently modified and extended by others, it will fall within the province of our Society to examine fully into this and kindred methods that may be devised for effecting rapid interchange of intelligence in towns.

The questions of field telegraphs and torpedo connections are other branches of inquiry to which we shall have to give our attention, and to these may be added the art of combining secret codes and semaphore signals.

These remarks may suffice to show how great is the field for our activity, and how much remains to be accomplished notwithstanding the extraordinary progress of which we are apt to boast.

I am happy to state that papers on several of these subjects have already been promised by leading members of our body.

Before concluding I have to ask you in the name of your Council to give your *post factum* approval to several of our acts which strictly speaking should have been submitted to you for approval beforehand. We have taken upon ourselves to elect, without ballot, several distinguished men who had not joined our Society on the outset; we have admitted Foreign members upon terms different from those originally laid down for general membership, and we have postponed this opening meeting from the month of November, which was the time originally fixed upon, till the end of February. We may plead in excuse that we have been guided in these matters solely by the desire to give stability to our enterprise, by collecting in the first place the elements necessary for its success.

I consider it a most fortunate circumstance for our Society that through the liberality of the Council of the Institution of Civil Engineers we are enabled to hold our first meetings in these commodious rooms, under the roof of the parent Institution of Engineers, and with their good wishes to cheer us on our way. May our success justify their liberality, and may we all have reason hereafter to feel that we have accomplished a useful task in contributing towards the formation of the Society of Telegraph Engineers.

Mr. R. S. Culley: I beg to move a vote of thanks to the President for his address, and that he be requested to allow it to be printed and circulated amongst the members. I would also include in that motion our thanks to him for having consented to become the President of this Society, and for taking the Chair this evening.

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Mr. Latimer Clark: I have great pleasure in seconding the motion. I feel that this evening we have been assisting in the planting of an acorn which will some day grow to a goodly tree. There is to me something peculiarly interesting in being present at the inauguration of what I trust will be a long-enduring and important Society. And it is a great pleasure to feel that this Society has been established while many of the oldest members of the art of telegraphy are still living. We have Ronalds, Wheatstone, Cooke, Bain, and a host of other names which must ever be associated with the history of telegraphy in this country, still among us, and I think it a fortunate thing and an honour to have so many of their names as members of our Society. One—Sir Francis Ronalds, the pioneer of all—I would particularly mention on account of his venerable age, and the earnest and persevering efforts he made to introduce the art of Electric Telegraphy into the public service, at a time when the world was not yet ripe for it. I have always felt a peculiar interest in Sir Francis Ronald's career. As early as 1818 he proposed his system of telegraphy, and although but a private individual, he went to the expense of erecting some miles of telegraph wires in his own garden at Hammersmith, in order to prove its practicability. But he was before his time, and nothing then came of it. In 1823 he wrote a very interesting book, now scarce, in which he described a very complete system of telegraphy, by means of which he said he hoped to see the day when the King at Brighton would be able to communicate with his Ministers in London. Unknown and forgotten by his generation, he lived for many years the life of an exile in Italy—but his prediction was abundantly fulfilled. That day has arrived and passed, and at the age of 90 years Sir Francis Ronalds still lives to witness the triumphs of the science he introduced. He has deservedly though tardily received the honour of Knighthood for his services, and I rejoice to feel that he is a member of our Society. I feel assured that this Society will grow and increase, and that it will ultimately become a large and important institution. If you read the scientific works and periodicals of the day, you cannot fail to perceive that electricity, magnetism, and electric telegraphy occupy a large and increasing share of public interest and attention. I hope, therefore, that this Society will develope into something more than a mere Telegraph Society, and that it will gather into the compass of its proceedings a large share of the many valuable and interesting papers

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which we now see read before other Societies, and scattered among other scientific publications. When that time arrives, and not till then, I shall feel that the Society of Telegraph Engineers has assumed its proper function and position in the scientific world.

THE PRESIDENT: If it is the pleasure of the Society that this motion be adopted, which I beg you to signify by holding up your hands, I shall have great pleasure in placing my address at the Society's disposal.

The resolution was unanimously adopted.

THE PRESIDENT again rose and said: Our business to-night, gentlemen, is to consider the Rules of the Society, which have been put into your hands, but which have not yet received the formal sanction of the members of the Society of Telegraph Engineers, such as is now constituted. If any Member has observations to make on these rules he may now do so [a pause]; but if no observations are offered, I will put it to the vote, whether these rules as at present drawn up shall be the laws governing this Society; they may be amended from time to time as occasion may arise, but it would be desirable, certainly, if they were adopted for the present in order to remain in force until we have seen whether they are or not suitable to the necessities of the Society. These rules have been sent to every member of the Society, and since no objection has been raised, I will put it to the vote, whether they shall be adopted as th laws governing our future proceedings.

The rules as presented to the meeting were unanimously agreed to.

THE PRESIDENT: I declare these rules to be the statutes of our Society.

THE PRESIDENT: The Honorary Secretary will now read the names of candidates for election, who, having been passed by the council, should be balloted for this evening.

Major BOLTON (hon. sec.) having read out the names,

THE PRESIDENT said: These are 23 names, which if accepted by you, will form a considerable increase to the members of our Society. If we include the foreign members who have already signified their intention of joining, our Society will already count from 150 to 160 members of all classes, and I hope that number will be speedily increased to 200 or 300. Considering the insufficiency of balloting boxes at our hands, and to save your time, I propose that you on this occasion dispense with the formal ballot, but elect those gentlemen who have

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all been approved by the Council by show of hands. I will read over the names, and I will only ask gentlemen to hold up their hands who are against this mode of election of any particular candidate. [The list having been read without dissent—THE PRESIDENT added]: In the absence of any opposition, I declare these gentlemen to be elected associate members of the Society of Telegraph Engineers. I will now call upon members to express their views regarding the general question of the direction and development which should be given to this new Society.

Mr. C. F. VARLEY, F.R.S.: Mr. President—Every person who has had the pleasure of listening to your address, must feel considerably relieved from the responsibility which naturally attaches to those who have been directly or indirectly connected with the formation of a new society: for it has been the opinion of many, and I myself entertained the same opinion, that telegraphy alone was a subject scarcely large enough to keep a society like this on its legs. But after your address, Sir, no one will fail to see an extensive field is open for not only keeping the society employed, but usefully so. This society, I assume, will gradually, by natural selection, develop more into an electrical society than into a society of telegraphy proper; and the moment it is understood that all papers on electricity, or bearing directly upon the development of electrical science are admitted, it at once takes the science out of the narrow groove into which it seemed to be drifting, into the most extensive of all grooves, because it will be found ultimately to embrace every operation in nature. The moment it is understood that electrical papers generally will be admitted, we open a field to all those sciences in which electricity plays an important part; and the only difficulty that I see we may have in dealing with those papers, will be not to give offence to other societies by admitting papers which they may consider as properly belonging to them. It is scarcely possible to conceive chemical action which is not an action influencing or influenced by electrical law; therefore I do not see how the Council in some of the papers that will come before them are to decide whether they should belong to this, or to the chemical, or to any other society; nevertheless, should a paper by accident get upon the wrong line, I hope it will meet here with a hearty reception. Therefore in that sense we shall get out of the difficulty on that score. The introduction of other means of communication, is at present limited we

may say, to the pneumatic system, for that is about the only system of telegraphy yet that is likely to grow very widely. There is a shrewd proposition by a gentleman in Glasgow, that the *Daily Telegraph* and other newspapers, inasmuch as they communicate intelligence at a distance are telegraphs, and on that score the society would open itself to the reception of papers on almost every subject connected with the press. But, fortunately, it will not be difficult to define what papers come properly under the head of telegraphy, and what do not; for, I presume, it will be fairly understood to mean telegraphy, such as electric telegraphy, or those means of communication which have been brought into operation by the telegraph. But the introduction of systems of codes, though exceedingly important to the public at large, I scarcely think to be matters of so much importance to a society professing, and constituted chiefly, of the engineering element. Nevertheless, as they do develop the practical utility of the telegraph by enabling those who cannot afford to use the telegraph to use it, by assisting those wanting to send great quantities of intelligence on special occasions, it may still become so important a branch of this great system of communication, that I do not see how it is possible to draw a line to separate those parties, and say they are not fit to come into this society; and, therefore, whether we look at the construction of a battery, the manufacture of a telegraph pole, or the laying of a submarine cable, it is difficult to say where to withstand and where to receive. The list of names of members who have already joined us is very encouraging for a society so young, and as we have the support of so many gentlemen known abroad as representatives of the telegraphs of the different foreign governments, and as it has met with such a warm reception from them, I think it is not too sanguine on our part to assume we have within ourselves the means, if we develop it, of making this a very useful and influential society.

Captain Dawson, R.N.: As a visitor, may I be allowed to ask a few questions. You have explained, Sir, very fully, that the Society intends to discuss the application of electricity to civilised purposes. Do you propose to discuss its application to the uncivilized purposes of war?

The President: I think I should ask for a little explanation of what you mean by "uncivilized purposes."

Captain Dawson: The uncivilized purposes of civilized war. Whether you include the ignition of gunpowder within the purp

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of telegraphy? or do you draw a distinction, so as not to admit that subject?

The President: The means of exploding torpedoes is a subject which we hope to have before us: and we have a paper promised by Major Stotherd, R.E.

Mr. W. H. Preece: I came here quite unprepared to speak to night. At the same time, I feel after the admirable address we have received from you, and after the expressions that have fallen from others, upon the scope and prospects of this Society, I cannot hesitate to express my approval of the path you have laid out before us. I heartily agree with Mr. Varley in the fact that we must expect to be driven into other paths than those of telegraphy. I conceive there are many persons associated with telegraphy, who have made electricity their study, who have long sought for some mode by which the results of their studies and ideas may be circulated, and I think the establishment of an institution of this kind, with the probability of having its minutes regularly published, will induce many to study and examine for themselves, questions which require solution. Those who are connected with the practical development of telegraphy, constantly come across knotty questions on interesting points that require elucidation, and there are many persons, who, for their own sakes and curiosity, carry out very elaborate experiments which are never brought before the world, simply because there has hitherto been no medium through which it can be done. I consider this Society will, in that respect, fill a wide gap. The Society may do more for the advancement of telegraphy than any other Society can do. I beg to thank you, Sir, for your address, and as a prognostication for the future, I come here to night, to propose eight new members.

Mr. Phillips, Jun.: As I have two or three foreign members to propose I should be glad to be informed whether or not there is to be only one grade of foreign members whose subscription will be one guinea per annum? or is it intended to have the two grades of members and associates? As I am about writing to some friends engaged in the Persian Gulf I should like to understand clearly what the rule is in that respect.

The President: I will ask the Honorary Secretary to be good enough to read a resolution lately passed by the Council relative to foreign membership.

Major Bolton read the rule accordingly.

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Mr. PHILLIPS expressed his satisfaction.

THE PRESIDENT: There is one other subject to be now ventilated—That is the form which our publication should take. Some have suggested the publication of the transactions in volumes according to the necessities of the case—to publish a volume when the subject-matter has accumulated sufficiently: others have suggested that a journal appearing at regular intervals would more completely represent the kind of progress with which our Society will have to deal. Without giving my own opinion on the matter, I should be glad to hear an expression of opinion on that important subject, on which, I need hardly state, no decision has yet been come to by the Council.

Mr. WARREN: There is one observation I would make. It is the practice of many learned societies to copy into their publications from other journals, especially from continental journals, different pieces of information relating to the science treated of, and I venture to think that would be a good plan to be adopted in the case of the publications of this Society.

Professor FOSTER, F.R.S.: The question brought forward by the last speaker is, I think, practically a very important one as regards the utility of the Society. It seems to me if we can manage to give a record of electrical science in our proceedings we shall be doing what will be of great service to science as well as of great practical utility for the advancement of telegraphy. We have in this country no means of reproducing foreign works on electricity at all systematically. The Philosophical Magazine I believe is the only journal in which such papers are reproduced in full; but even in that, there is nothing like a systematic report of foreign works, and I agree with Mr. Warren that one of the most useful things the Council could attempt would be a systematic report not only of publications relating to the practical working of telegraphy but to the other sciences that are allied to it. As to the form of publication, that is a matter which depends upon so many considerations that I think we cannot discuss it with advantage on this occasion. The amount of funds at our disposal is the first point to be considered. I suppose the question of money would go farthest to decide the actual mode of publication, and also whether the publication should be serial, or only at intervals when we have sufficient matter; but that in our proceedings we should establish a report upon electrical science seems to me exceedingly desirable.

Capt. COLOMB, R.N.: I have been asked to perform, what is to me

a very pleasant duty, namely, to propose a motion which I am sure you will agree to with acclamation, viz., a vote of thanks to the President for his conduct in the chair. There was originally a reason why I should make a good long speech, but happily the interesting speeches we have had from other members have removed that necessity. Therefore I have great pleasure in asking you to give your thanks to the President; I think I may say, not only for his conduct in the chair, but for undertaking, with his great name, to start a society of this kind. Everybody knows the difficulty of starting a new thing. Most people know it so well that very few have spirit and self-abnegation sufficient to undertake that duty. I had not the pleasure of our President's acquaintance before I came on the council of this society, and I am perfectly satisfied that had he not personally worked as I know he has done, we should not have been in the favourable position we now are. Not only has he worked for us on the council, not only has he guided us by his wisdom to the extent we have seen, so that no member has been able to find fault with our proceedings up to the present time; not only has he done that here, but he has represented us at Rome while attending the conference there in a way that has drawn those replies which he read to you. He has given us already a European name, and a European reputation. I want to say just one little word on a matter which I think has not been put quite clearly before the meeting. It is that the society does not confine itself to electrical telegraphy. It takes in all questions connected with electricity, whether directly or indirectly connected with telegraphy, but it also takes into view all methods of communicating to distances by signs. I am myself here on the council as the representative of a form of telegraphy which has nothing to do with electricity, viz., that carried on by visual signs at sea; and the mere fact of my being on the council shows the very wide scope which the society proposes to take. I think I need add no more words. I am sure you are all prepared to accord your most cordial thanks to our President and Chairman for taking up the society as he has done, and giving it the foundation he has, for his inaugural address, and also for his able conduct in the chair to-night.

The motion was passed by acclamation.

THE PRESIDENT: I am sure my friend, Captain Colomb, has done me more than justice in the remarks that have just fallen from him. I cannot boast of being the originator of this Society. The Society

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was originated by several of my friends about me before I joined it, and if they have done me the honour of proposing me for the prominent position I now occupy, they, and in fact the whole body of original Members, have given me a proof of confidence for which I can only thank you in doing my utmost to promote the objects of the Society. You should not lose sight, however, of the fact that our success up to this point in forming the Society of Telegraph Engineers, is due in a great measure to the co-operation of our Honorary Secretary, Major F. Bolton, who has given much personal attention to this matter from the very first.

The Meeting then adjourned till the 13th of March.

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The Second Ordinary General Meeting was held on Wednesday, March 13th, 1872, C. W. SIEMENS, F.R.S., President, in the Chair.

The following paper on "Automatic Telegraphs" was read by Mr. R. S. CULLEY.

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The advantages of machine over hand labour are as apparent in telegraphy as in any other mechanical act, even without regarding speed, for signals mechanically sent will always be better formed, and more legible, than those sent by the key. But we are able to show, from experience, that besides assuring better signals, a greatly enhanced speed can be attained by the automatic system.

My intention, in this paper, is to speak only of those automatic systems of which I have personal experimental knowledge, and I am in consequence obliged to pass over more than one of great merit; among them, that bearing the name of our worthy President.

The system of Alexander Bain was the first that was actually worked in this country, and the method of signalling by means of perforated paper, which is, I think, employed in all systems, was introduced by him. It was tried between London and Birmingham, or Birmingham and Gloucester, in about the year 1850, and I myself used it between Manchester and Liverpool in 1852. It failed, partly because the insulation of the wires was too variable to allow of rapid signalling except in fine weather, but mainly because we had no good punching apparatus. I revived it some three years since betwe

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London and Southampton, attaining a rate of 60 words per minute, and should have continued the trial had it not been that such an arrangement had been concluded with Sir Charles Wheatstone as rendered it unnecessary to attempt to improve a method radically inferior.

Bain perforated the paper ribbon in such a manner that the punctures represented the Morse signals themselves, but, as it were magnified. A wire brush rested on the ribbon, and made contact with a metal wheel through the holes in the paper. This plan has several objections; dust or fibres of the paper are apt to interfere with the contacts, and what is more important, the edges of the perforations act upon the brush in a manner which prevents it touching the metal wheel over a considerable portion of the space allowed for contact. Better results were obtained by lengthening the perforations in the paper, and running the machine proportionately faster. The system employed by the Postal Telegraph Department is Wheatstone's, in which the contacts are made between levers and studs, the paper being used only to regulate the movement of these contact pieces. This arrangement gives much more uniform and trustworthy contacts than can be obtained between a brush or spring and a revolving wheel, and affords great facilities for the production of the compensating currents, which are required at high speeds. The principle of the apparatus is that the armature of the electro-magnet, which causes the printing disc to touch the paper, shall not have a tendency to leave the paper when the marking current ceases, but shall remain always in the same position in which it is left by the last current. The machine is arranged to send a series of reversals or alternate + and — currents at definite and regular intervals, and the function of the perforated ribbon is to decide whether these currents of either sign shall or shall not pass out to the line. An ebonite rocking beam (R, *Fig.* 1), moved by wheel-work, carries three pins, that on the left hand is connected to "line," that on the right hand to "earth;" the centre pin is insulated, and serves to connect the curved lever (B, *Fig.* 1) with one or other of the battery levers (Z, C), according to the position of the rocking beam. Under the beam lie the two levers (A,B). These levers are pivoted independently, but are in electrical connection through the spiral springs (H, H$^1$) attached to them, and through the frame of the instrument. On the ends of these levers (A, B) are pivoted the vertical needles (V, V$^1$). The one (V) regu-

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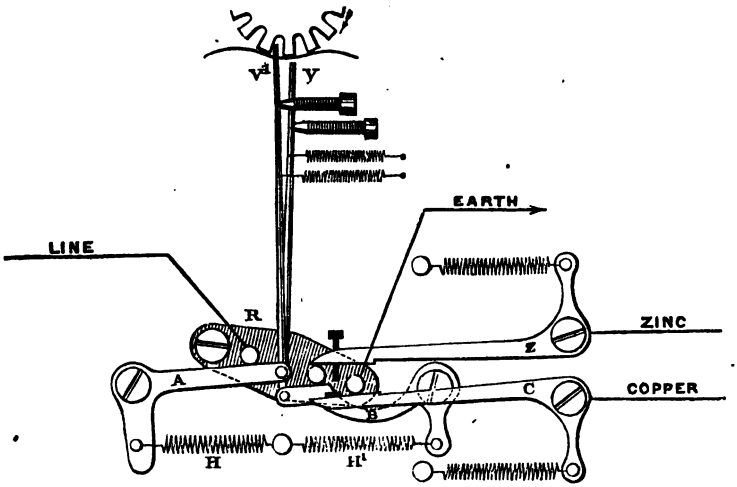
lates production of the marking, the other ($V^1$) that of the reverse or spacing current. These levers are not *fixed* to any of the moving parts of the apparatus, but are simply pressed upwards by the spiral springs (H, $H^1$, *Fig.* 1) so as to follow the movements of the rocking beam, and remain in contact with the pins inserted into this beam so long as their upward movements are unchecked. The needles attached to these levers determine whether line-contact should be made or broken at the moment battery-contact is made. They rise alternately until they touch the paper ribbon; if there be a hole opposite their points they pass through it, and the contact is undisturbed; but should there not be a hole, their motion and that of the lever is stopped, and the pin on the rocking beam continuing to rise, contact is broken between it and the lever.

*Fig.* 1 shows the apparatus in a position for sending a negative current. The levers Z and C are the poles of the battery. The

FIG. 1.

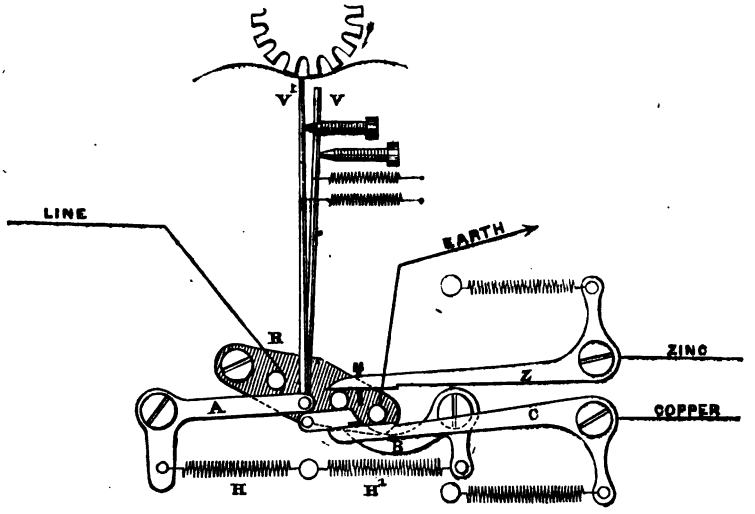



lower lever C touches the right hand pin on the rocking beam, and as this pin is in connection with the earth, the copper pole is in connection with the earth also. The upper lever Z, which is in connection with the zinc pole of the battery, rests on the centre pin of the beam, and is in connection with the line through the lever B, the spiral springs H, $H^1$, and frame of the instrument, the lever A and the left hand pin; and thus a *negative* current has been sent to line.

*Fig.* 2 shows the position when the current is broken. The risi

of the lever A is prevented by the paper, the vertical needle $V^1$ attached to it not meeting with a hole in the ribbon. Here the contact between the lever A and the left hand pin is broken, and no current passes on to the line.

FIG. 2.




When the speed of transmission is increased beyond a rate which varies with the length of the circuit, embarrassment arises which is partly due to induction when the potential of the line wire varies with the interval between the currents, and partly to what may be called the "inertia" of the electro magnet of the receiving apparatus, the time occupied by the magnetising and demagnetising the iron, varying also with the interval between the currents, and probably even in a comparatively short suspended wire line not more than 70 words per minute could be attained under Bains's method where the currents are sent precisely in the same manner as by an ordinary single current key.

With reversals speed is increased, but is still considerably lower than the maximum to be attained on a given line. It is well known that a succession of equal currents of opposite signs, at equal intervals, will give perfectly distinct *dots* at a very much higher speed than the *dots* and *dashes* of an alphabet can be produced.

Wheatstone's apparatus produces the Morse signs by currents of equal duration; or, in other words, by a succession of *dots*, but as the intervals between the currents are necessarily unequal, the alphabet more slowly produced than a series of equidistant *dots*. The speed

of a succession of letters (an alphabet) depends also on the distance between the letters, the *greater* the interval the *slower* the speed, because an additional element of variation in the electrical condition of the wire and the magnetism of the receiver is thus introduced. Speed is generally limited more by defects in the formation of the letter than by the loss of dots, or running together of marks, and the defects are greatest where there is the greatest irregularity in the intervals between currents, as for instance, in F _ _ ___ _ R _ ___ _ It is necessary, then, to apply a system of compensating currents to maintain as great a uniformity as possible in the condition of the wire and electro-magnet.

This was effected in the first instance by bridging over the break in the circuit which occurs when the pin is stopped by the paper, by resistance coils, so that a weak current was sent in the interval of break, the strength of which currents was regulated by varying the resistance. This system was further improved upon by an alteration of the transmitter by which the compensation was more accurately applied, and it is upon this principle the apparatus is at present constructed, although experiments in a different direction are in progress which may bring about a further improvement in the system.

*Fig.* 3 is intended to represent a piece of the perforated ribbon, the perforations which regulate the contact making portion of the transmitting apparatus are represented by the larger circles, while the centre row of holes is represented by the smaller circles, by this row of holes the paper is carried forward in the transmitter.

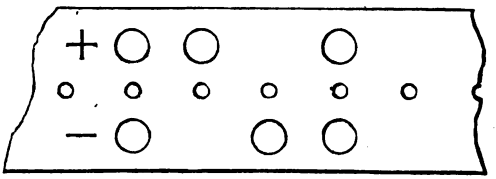


FIG. 3.

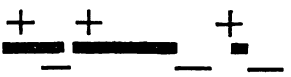


FIG. 4.

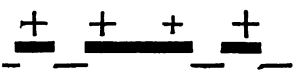


FIG. 5.

The signs + — show the direction of the currents, the larger signs indicate the signalling currents, the smaller the compensating

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The slip is perforated for the letter R of the Morse alphabet, this letter has been selected as being one which is always much deformed, and which shows the effect of a dot preceding and following a dash. The upper row of holes is that which allows a positive or marking current to be sent when the vertical pin V (Figs. 1 and 2) of the transmitter passes through one of them. The lower row of holes allows a negative current to be sent in the same way when the vertical pin $V^1$ (Figs. 1 and 2) of the transmitter rises through one of them.

*Fig.* 4 represents the letter R of the Morse alphabet, as received at a high speed on a line where the original system of intermittent currents is used. It will be seen that in the case of the dot before the dash, a +, then a —, and finally a second +, that is two positive, and one negative current are sent to form the dot and to commence the dash; that is, twice as much positive as negative current, and the dot is consequently much elongated, and has a tendency to run into the dash. In the case in which the dot follows the dash, it will be seen that the case is exactly the reverse of the former, and for the finish of the dash a — current is sent followed by a +, and finally by a second — current, the last two to form the dot; that is two — and one + current are sent, so that in this case the line is charged negatively in excess; consequently the space between the dash and dot is considerably increased, and the dot much shortened or lost altogether.

*Fig.* 5 shows the same letter R as received where compensating currents are used, and is perfect with respect to the length of the marks and the spaces between them. The compensating currents are represented by the smaller signs. It will be seen that before the commencement of the dot the line is charged negatively, instead of being left clear as in the original system, and prevents the elongation of the dot before the dash as already explained.

In the case of the dot following a dash, it will be seen that a positive compensating current is sent before the terminating current for the dash, so that the line is not too much negatively charged as where no compensating currents are used, and the elongation of the space separating the dash from the dot as well as the diminished size of the dot itself is prevented (Fig. 5).

The principle of compensation is, I am aware, not new; but I think no practical way of applying it has before been proposed.

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In a circuit composed partly of over-ground wires, and partly of buried or submarine wires (and all our circuits contain a considerable proportion of buried wire), the position of the underground work or cable will effect the speed at which the two stations can receive from each other. If the buried portion or portions be symmetrically placed with respect to the two stations, as when the land lines at each end of a cable are of equal length and resistance, the two stations will be able to read each other equally well; but if the land lines on one side be much longer than the other, the rate at which the station at the end of the shorter land line will be able to receive, will be *less* than that at which the station situated at the end of the longer land line can receive from the other. This difference of speed is sometimes very considerable, and the difference is the greater as the lengths and resistances of the land lines on each side of the cable are the more different.

The London and Amsterdam circuit is composed of, first a suspended wire of 130 miles, then a cable of 120; lastly, on the Dutch side, a suspended wire of 20 miles.

Here it was found that the relative speeds of signalling were as 9 to 6, the higher speed being Amsterdam to London. The rate to Amsterdam was increased by decreasing the resistance of the batteries; and still further by the insertion of a high resistance (as much even as 5,000 ohms) at Amsterdam (in the receiving circuit only) to delay the discharge of the cable.

But in the case of the London Dublin circuit, where the land lines were 266 and 10 miles respectively, and the cable 66, in all 342 miles: the addition of Resistance at Dublin in the receiving circuit has no appreciable effect, because the length of land line on this side, is too great to permit the cable to be sufficiently charged. Here the speeds are 40 and 80 respectively. In fact, the speed to Cork from London is 38 words, or nearly as high as London to Dublin, though the distance is greater, the English line being 298, cable 62, and Irish line 124 miles, or in all 484 miles. Here the resistance per mile of the line wire is less, the wire being of a larger gauge; but the more central position of the cable has a considerable effect. Moreover, the resistance of the English line, is equal to only 149 miles of the Dublin line, so that the potential of the English end of this cable can be raised above the corresponding end of the Holyhead cable. The apparatus, as at present made, can be arranged either to send what are

technically called "permanent" currents, or to represent an ordinary double current key, or, 2ndly, to send short initial and final currents separated by an interval of insulation, called the "intermittent" system, or, 3rdly, a strong initial and final current, each followed by weaker currents of the same sign, the strength of which can be regulated with great exactness by the amount of resistance which is placed in the battery circuit. This is called the "compensated" system.

To practice the system of working is this:—If the weather be dry, and the insulation high, the "intermittent," or perhaps the "Compensated" system with a very high resistance, giving a very weak compensation current is used. When there is contact, the "permanent" system or the "compensated" with a low resistance. This is to keep out the stray current on the same principle as the double current key. In the case of contact it is sometimes found serviceable to add resistance at the receiving end of the circuit, increasing the battery power; this is simply to lessen the tendency to receive the leakages from the adjoining wires.

It has been already shown how resistance is used at the receiving end of the circuit where there are submarine cables. It is used on ordinary land lines for a similar purpose, that of balancing the position of buried wires. It is found that on *east* and *west* wires speed is decreased about noon. The cause is not clear, but it probably is due to the ordinary diurnal variation in earth currents. There may also be something due to the increased resistance of the wires from the increased temperature. In all cases speed is increased by inserting a shunted condenser at the receiving end.

There is also a very noticeable amount of embarrassment due apparently to the magnetic inertia of the electro-magnet of the receiver.

On short circuits it begins to be felt with "permanent" currents at 70 words; with "intermittent" at 100 words; and with "compensation" at an intermediate speed varying with the strength and duration of the compensation current. To overcome this defect we have been for some time engaged in experiments for the purpose of dispensing with the electro-magnet, adopting the well-known principles of a light moveable helix and a large fixed magnet, or a helix within a helix. It may be interesting to state the actual speed attained in practice with the Wheatstone apparatus.

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|---|---|---|---|
| To Aberdeen ... | ... | 60 words per minute. | |
| „ Sunderland ... | ... | 90 | „ „ |
| „ Manchester ... | } | | |
| „ Liverpool ... | } | 120 | „ „ |
| „ Cardiff ... ... | } | | |

In some cases as many as four intermediate stations are introduced on the circuits devoted to the press, on which 1,000 words are sent simultaneously to each station in 20 minutes with regularity. For news-work the ribbons are punched in duplicate, or even in triplicate, and the same ribbon is used for several sets of stations in succession. Indeed, were it not for the automatic system, it would be impossible for the Post Office to convey the large amount of matter handed in by the Press Associations.

The perforating apparatus contains three sets of punches, actuated by three levers, for the dash, dot, and space respectively, and the paper is perforated by striking the ends of the levers. The operation is very much facilitated by the pneumatic apparatus, in which the levers are struck by pistons actuated by compressed air. Three keys like those of a pianoforte open the valves, and the touch is so light that three or even four ribbons can be perforated at the rate of 40 words per minute by a female clerk, if experienced.

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The President called upon the members to discuss this paper, and suggested that, in order to proceed systematically, any questions should first be asked to which Mr. Culley could reply in further explanation of the apparatus he had described.

Mr. G. Preece asked what staff was required in the use of these instruments?

Mr. Culley said that could be best answered by Mr. Eaton, but of course 120 words per minute were not got through with one writer. The action being automatic, the object was to get the utmost possible amount of duty out of the wires, and that could only be done by the co-operation of several writers.

Mr. Eaton stated that seven or eight clerks were required at each end. The staff necessary was three punchers, one person to attend to the apparatus, and three or four writers.

Mr. Culley remarked that it did not pay to use automatic apparatus on short lines; it was cheaper to put up extra wires. There were limits within 100 or 120 miles, where it did not answer to employ automatic apparatus if they had room to put up more wires.

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A MEMBER asked whether any instrument had yet been made to overcome retardation of the negative current?

Mr. CULLEY replied he could not say it was made, because it was not yet finished, but such an instrument was in course of being made. It had been tried roughly. It was the plan adopted by Thomson with a syphon recorder, and was in use many years before that.

THE PRESIDENT said there were many points of interest connected with these instruments, particularly that of the currents for the absorption of the positive by the negative current, and also the retention of the charge in the wire by introducing the resistance at the end. There were most interesting points on which he should be glad to hear observations.

Mr. S. PHILLIPS, Jun., inquired what battery power was used for these instruments?

Mr. CULLEY replied about half as much again as was used for the ordinary Morse, or from 60 to 80 cells according to circumstances.

Mr. W. H. PREECE (responding to the President's invitation) said the subject had been so well nigh exhausted by Mr. Culley, that there was but little left for him to say; but there were one or two points on which perhaps some members would like information, which it might be within his province to impart. Perhaps the first question that would occur to the minds of some was—what are the immediate advantages which are gained by the introduction of this automatic apparatus? And again, what are the disadvantages of it? because in telegraphy, as in everything else, what they gained in one direction they were almost sure to lose in another. And if in this particular apparatus they gained in speed, they might lose in something else. The great advantage which they derived from the introduction of the automatic apparatus was this—that all those little defects common to human nature were remedied in the machine. It secured greater accuracy, and greater accuracy meant greater speed. One of the greatest possible mistakes made by telegraphists and people who studied telegraphy was this—they fancied that the Morse alphabet was made up simply of dots and dashes. The essential element in connection with the Morse alphabet was the space, and the space could never be so accurately formed by the human hand as by the machine. Machinery was the only means by which this could be continuously done; and in all automatic apparatus of any description the first great advantage and benefit to be derived was getting the

spaces precisely made, and therefore getting the messages sent accurately, and the avoidance of the frequent mistakes which occurred from hand manipulation. Not only did accuracy arise, but speed; because want of accuracy meant repetition of messages, and other causes which delayed messages. The direct advantage from automatic sending was, therefore, greater accuracy. Again, the human hand and mind rapidly tired—the machine did not. The result was they had apparatus which would work for years and never tire, and by that means they got the maximum work out of their wires. On the other hand they delay. The act of punching, the act of preparing the message, and the various processes it had to go through before it passed through the transmitter, involved delay, and the result was the messages transmitted by these means invariably incurred delay, trifling when taken in the aggregate, but which could not be admitted in short circuits. One great point with Mr. Scudamore, and those engaged in the management of the Post Office Telegraphs had been this—that no message from one part of England to another part should incur a greater delay than five minutes; that anybody going into a telegraph office could feel sure that his message would be forwarded for delivery within five minutes. That was a limit which was not always practicable in large towns, but it was a limit that would be eventually obtained; but it was impracticable in the case of the automatic apparatus, for experience had shown them they must meet with a delay of something like fifteen minutes on the average. The next point to be considered in connection with this system was that of expense in regard to the number of persons employed. They had heard, that in the case of transmitting 120 words per minute, they required the services of seven clerks at each end. The average, as far as his experience went, over the numerous automatic circuits they had, was five clerks. What did that mean? It meant that, to increase the capacity of their wires from thirty or thirty-five words per minute to sixty or seventy words—which was the average velocity of the automatic system—they must increase the staff from two clerks to ten. Now clerks they knew could not live on nothing, and that meant expense; and, as he had shown, the increased capacity of the wires was about double. This problem, therefore, arose, taking on the one hand the double capacity of the wires and its increased staff, and on the other hand the ordinary working apparatus with its small staff, how far were they justified in doubling the working by the introduction

of the automatic wire, or for how short circuits were they justified in adding to the wires instead of applying that automatic apparatus. The practical solution of the problem was this:—That the automatic apparatus, economically speaking, could not be applied to less distances than 200 miles. Within that distance it was better to increase the number of wires; beyond 200 miles it was better to employ the automatic apparatus. The result was, the automatic system had been applied to all the long circuits with the greatest success, and the amount of work got out of their wires was something startling to old telegraphists. Such an enormous increase of business as they had to meet in this way was never expected, and they found what with the increase of messages, and what with the increase of press work, if they had not this special apparatus they never could have met the requirements of the day. Mr. Culley had given them an idea of the amount of work done in one night. It was worth knowing, that in one night the amount of work done in Telegraph Street, was very nearly as great as that done in the day. Mr. Culley had told them they had on occasions transmitted 400,000 words a night, and on some circuits they were sent through to 5 or 6 stations simultaneously, and the result was, by a rough calculation he had made, that every night somewhere about 2 millions of words were transcribed (he did not say sent) by the telegraph clerks: and taking a column of the "Times" to contain about 2,000 words, it followed that about 1,000 columns of the 'Times" were telegraphed every night. There was one economical point on which this automatic apparatus had proved of the greatest value, and that had been in the case of breakdowns of wires. They all knew it was impossible to provide against breakdowns. The business was very large indeed, and the consequences was, the wires were gorged with messages. Say between London and Manchester, they had 6 wires gorged with messages, and a breakdown occurred to 4: the result would be that the whole of this enormous work would be thrown upon 2 wires. Serious delay would result. In such a case the automatic system enables them to clear off the work, and get it through to the satisfaction of the public. The probability was that over the whole Post Office system to all the great stations the automatic system would be universally employed. Mr. Culley in his paper alluded to the system of compensating currents which were shown in the diagram, and without which it would be impossible for

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this system to work as satisfactorily as it did. Mr. Culley was quite right in saying that was not done on the Bain principle, but he (Mr. Preece) knew that the introduction of the compensating current in the particular apparatus employed by the Post Office was entirely due to Mr. Culley himself, though that gentleman with characteristic modesty kept the fact in the background. He had no further remark to make except this,—with regard to the Hughes automatic apparatus. —He believed he was quite right in saying they tried the system of automatic working in Italy, and it was not very successful. The experiment had been tried in various ways by Mr. Culley and it had been successful, but it had been abandoned for the reason stated, though he (Mr. Preece) thought that was not a good reason. The fact was they could not exceed a certain limit in the working of the Hughes' apparatus: beautiful and perfect as it was in construction, it only attained a speed of something like 60 words per minute. Now by manual labor they could only sustain that limit for a time. Men tired and clerks varied very much in physical and physiological capacity. With the automatic apparatus, that limit could be maintained for an indefinite time and therefore he thought more experiments ought to be attempted to obtain that particular system of automatic sending which would reach the limit of speed attained by the Hughes' apparatus, and when that was done, it would stand as one of the most beautiful apparatus ever produced.

Mr. Culley remarked it had the advantage that it gave all the combinations. That was a technical term, for sending two or more letters in one revolution of the contact. It required a very excellent clerk to recollect all the letters that could be sent in the same revolution. It required practice to send them; but by punching they could understand every combination being used. No doubt they could run the contact at 110 revolutions per minute, so that if three letters could be sent in a revolution, three times 120 letters could be sent in a minute; 120 revolutions per minute was rather fast for the machine to run, and it was hardly possible to run much quicker than that.

Mr. Preece said what he meant was, however perfect they might make the human machine, they might make this machine as perfect.

Mr. Radcliffe asked whether he believed that in the Wheatstone machine there was an arrangement which regulated the spacing?

Mr. Culley explained there were three keys in the Wheatstone

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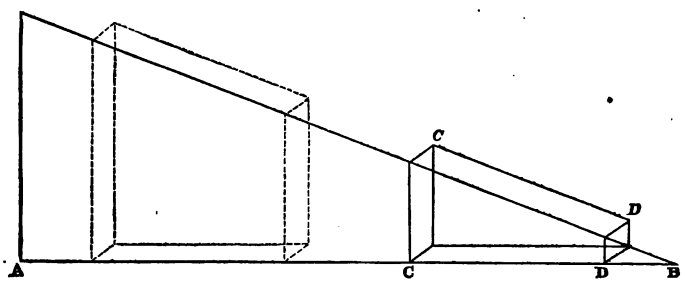
punching machine—the right hand key made the dashes, the left hand one the dots, and the centre one the spaces. The spacing in some measure depended upon the clerk.

Professor Foster said he had been very well repaid for attending the meeting this evening, and had been much interested by Mr. Culley's paper. There were several points of interest which struck him in the reading of it in an electrical point of view, on which he would like to hear a little more. One point especially was the difference of speed in opposite directions through a line, partly suspended and partly submarine when the submarine portion was at different distances from the two ends. He confessed he did not see the explanation of the fact in the instances given by Mr. Culley. To take the case from London to Amsterdam, he did not see how the speed would be increased by having resistance at the Amsterdam end. It struck him as a point of interest, and one on which he should be glad to hear some further explanation.

In reply to the remarks from Professor Foster,

Mr. Preece thought he could show on the board why there should be that difference—




Supposing that A B be the whole length of the circuit, A C and D B being line, and C D cable, constituting an imaginary line, say in sections of 130 miles, 60 miles and 20 miles. Now when a current is sent through such a wire, the potential of that current can be represented by perpendicular ordinates, and if a triangle be drawn then at any point of the line A B an ordinate raised there perpendicularly would give the potential at that point. Now we have to deal with a quantity dependent upon three variables; first the *resistance* then the *potential* and next the *capacity*. Now we know

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the capacity on the open line to be very small, while on the cable it is considerable. We can represent capacity graphically by a line at right angles or assumed to be at right angles to that representing resistance. The capacity of the open wires being comparatively nothing, can be neglected. The inductive effect or retardation of the current simply depends upon the quantity of electricity contained in the wire, and upon the means there are to discharge it rapidly. Now we can represent the quantity of the discharge by the solid figure CcDd, which is the proportion of the charge that remains in the cable, the rapid removal of which is the object to be attained. Now it will at once be seen that, according to the position of this charge, whether it be near one end or the other, so must the quantity of electricity be which flows out at one end or the other. The rate at which it flows depends, first, on the quantity of electricity itself retained by the cable; secondly, upon the resistance of the paths through which it flows; and, thirdly, upon the potential of this charge. The relations of these three quantities will fully account for the differences in speed which Mr. Culley describes. This is simply offered as an explanation of the cause why there should be a difference. I do not give it as a numerical explanation of that difference.

Professor FOSTER: That the position of the submerged part of the cable should make a difference was readily to be conceived, though it had not occurred to him before, nor was he previously aware of the facts. Still his question was, how the addition of resistance at this (Amsterdam) end of the cable increased the rate at which messages could be transmitted?

Mr. PREECE: I think I can give an explanation of that. If we assume that at one end of the cable the resistance of the line is small and at the other end very great, the result is that any waves, any currents of electricity which flow out at the further end have a very small effect in reducing the potential at the near end, consequently the current that flows is pretty constant and any variations in potential that occur at the near end are not only very small but are rapidly transmitted to the further end.

Mr. CULLEY added that the defective signals were due to the irregularity of interval between the different currents, and that the wire was sometimes charged in excess with a positive and sometimes with a negative current, and also that the signals will be affected by an interval during which no current is being sent, for the first signa'

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after a space during which the cable has had time to discharge will have a different effect to when the currents follow each other in rapid succession, and the effect of adding resistance appears to be to prevent the too rapid discharge of the cable between the currents, and prevents it changing its electrical condition so quickly as it otherwise would do, and renders the variation in the signals caused by the irregular intervals at which the currents are sent much less than when no resistance is inserted. But the insertion of resistance at the receiving end necessitates an increase of battery power, and as at the end of a long land line, such as London and Holyhead, on the London and Dublin circuit, the current is so much weakened before entering the cable, the insertion of resistance at the receiving end is useless, for the battery being so far from the cable the latter cannot be sufficiently charged to enable any added resistance to be of any service. When resistance coils are used at the receiving end, it is practically immaterial whether they are put between the line and instrument, or between the instrument and the earth.

The President remarked if they put the artificial resistance in form of a coil of insulated wire between the instrument and earth then it amounted to moving the instrument up on the incline of the diagram and of course any variation of potential at the new position of the instrument within the inductive circuit would amount to a greater positive quantity affecting the instrument than it would if the instrument were right at the end. In that case the inductive resistance should be placed between the instrument and the earth, whereas if more resistance beyond the cable line was desired in order to moderate the negative current it would not matter whether the instrument was placed before or beyond it.

Mr. H. Schütz Wilson: said he had not expected to have the honor of addressing the meeting and was but ill prepared to do so, because telegraphy was so rapid a thing that one's experience in it soon became as antiquated as the last fashion. He had been out of it for nearly two years, and in that period telegraphy had made such progress, that to return to it was like calling a person from the ancient world to revisit the earth in modern days. But looking to his own experience with the automatic instrument, he thought Mr. Preece had rather overstated the time required for punching and preparing the message for sending. He (Mr. Wilson) never found it take so long as a quarter of an hour to punch and prepare average

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messages for sending. He would place the time for that process at much less than a quarter of an hour; but no doubt in estimating the value of automatic apparatus they must allow for the time occupied in preparing the message before it could be sent. It was but a repetition to say that when machinery supplied the place of human labour, they did away with certain inconveniences, and with the variations of personal equation. He supposed he had had as large personal experience of human working in telegraphy as most persons, and he could say not only did it vary very greatly in different individuals, but varied from day to day in the same individuals. Any little derangement of the physical machinery or disturbance of the mental equilibrium had a great effect upon the rapidity with which human work was done. So far therefore as that point was concerned, the automatic was no doubt the more regular system, but he was quite satisfied it possessed no superiority over printing instruments when applied to short lines. The telegraphs of this country were now happily under government control and management. Under the old companies, commercial considerations prevented large views being taken of scientific requirements; everything was judged of by the commercial consideration of what it would cost, and how it would pay. Mr. Culley happily was not now hampered in this way, and he believed the results of that gentleman's endeavours had been valuable in proportion to the liberality and larger wisdom with which telegraphy was now treated. Under the present arrangements, speaking broadly, there was a clear advantage in the use of the automatic system in point of speed and precision, and the saving of circuits; they could work with fewer errors and more dependability. He considered the object of the paper was to elucidate the working of the automatic system, and he had great pleasure in expressing thus briefly this opinion upon it.

The PRESIDENT, in closing the discussion said, Mr. Culley had not pretended to give a description of all the systems of telegraphy, or of all the automatic systems of telegraphy. Telegraphic instrumentation was so great a subject that they could only hope to deal with it by degrees: but Mr. Culley had put before them in a very able and complete manner the automatic arrangements which had been adopted under his superintendence. He would not detain them by adding to the discussion, which had already extended to considerable length, otherwise he might have said something about the automatic system

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which had been established on the Indo-European line, and which was used to a considerable extent in Germany, differing from that now described. His experience confirmed the views expressed by some speakers, that where the amount of the business was limited, or for short lines, it was not worth while to resort to automatic instrumentation on account of the greater expense involved of maintaining a working staff. The automatic system was only advantageous, it had been proved for distances exceeding 100 or 200 miles, and for lines where the amount of business exceeds the capacity of the wires; but that condition was becoming more and more prevalent on all trunk lines in this country, and on the chief lines of European states. This was therefore a question of great interest and value, and he had great pleasure to move a vote of thanks to Mr. Culley for his very able paper.

The vote of thanks having been passed unanimously,

The PRESIDENT announced that a ballot was to take place this evening for the election of 27 associate members.

On the motion of the PRESIDENT, an alteration in Rule 3 was agreed to, by which members and associates were eligible for election at the age of 21 years instead of 23 years, as the rule originally stood.

The meeting was adjourned till 27th of March.

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The Third Ordinary General Meeting was held on March 27th, 1872, C. W. SIEMENS, Esq., President, in the Chair.

## (ANNOUNCEMENT BY PRESIDENT).

THE PRESIDENT rose and said: Before commencing our proceedings I have to announce to you that we have secured the services of Mr. Schütz Wilson as Secretary (hear, hear). Hitherto our friend Major Bolton has taken charge of all the business of the Society, but it could not be expected he should continue to do so, and it was very much to the interest of the Society that a gentleman with more leisure should undertake the office of Secretary. Mr. Schütz Wilson is well-known to most of you. For many years he held the post

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of assistant-secretary to the Electric and International Telegraph Company; since then he has devoted attention to literary and other matters, and therefore he is in a position in every way to do justice to the office he has very cordially accepted (hear hear). I can therefore only congratulate the Society on having secured the services of Mr. Schütz Wilson (cheers).

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## "A SKETCH OF THE PROGRESS OF SEA TELEGRAPHY."

The following paper was read

By Capt. COLOMB, R.N., Member of the Council S.T.E.

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Capt. Colomb rose and said:—Telegraphy has been defined as the art of conveying messages to greater distances than the voice can reach, and with greater speed than material bodies can travel; it is evident, therefore, that telegraphy must be carried on by signs, which are either visible or audible. The only difference I see between electric telegraphy and that description which I am about to treat of is that in electric telegraphy electricity intervenes between the operator and the signs he ultimately makes. In sea telegraphy, at present, the signs must be made directly by the operator. Setting aside the electricity then, it seems clear that the principles which govern electric telegraphy and telegraphy at sea must be the same. At the last meeting this view was strikingly confirmed in my mind by several remarks which fell from Mr. Preece. He gave us a sketch of the kind of mistakes that occurred in electric telegraphy, the difficulties that had to be overcome, and the dangers that had to be guarded against. Such mistakes, difficulties, and dangers, are exactly the same as those we have found it necessary to combat in carrying out telegraphy by sea. Electricity is not yet used in communication from ship to ship, or from ship to shore; the reason being that the electric telegraph at present requires that some persons should pass over the ground which is afterwards to be travelled by electricity, a condition of things which can never be secured at sea. But I think, and I

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believe electricians will confirm me in saying, we must expect a time to come when the progress of electricity will be such that the whole of what I have to speak to you about to-night, except the vital principles of telegraphy itself, will disappear; but until that takes place we must depend upon direct means of conveying our intelligence.

The art I am to treat of, is of very great antiquity. It seems, perhaps, a little far fetched to go back to the Hebrew writings for the origin of telegraphy, but it is as true as anything can be, that the Hebrew writers constantly mention methods of signalling from hill to hill, and from point to point. When we find the poet exclaiming "Lift ye up a banner upon the high mountains, exalt the voice unto them, shake the hand that they may go into the gates of the nobles," it is hardly exaggeration to say that in the present day, he would have expressed the same thought in the words "Send your telegrams far and wide." The word "Nes" commonly translated as banner, ensign, or standard, must be taken not to denote a Military Standard, but an arrangement of signals, for conducting the advance and retreat and movements of armies.

Coming down to a later period we find a passage in which telegraphy is treated of in the Agamennon of Æschylus written 500 years before Christ. The passage is too well known to need quotation, but it speaks of burning torches flashing intelligence from hill to hill and across the Ægean sea. Coming down still later to a writer equally well known, we find Polybius, 200 years before Christ expressing his opinion that in the affairs of war nothing is so important as the art of signalling by torches. Of course the art was extremely simple in those distant days. The wants of an army were few, the wants of the civil population were fewer, and they were very easily supplied by a few simple, well known signals. As an evidence of this simplicity, I might note that Polybius, in his disquisition on the art of telegraphy gives an instance when a Roman Prætor besieging a certain town had some friends within it who promised to throw the gates open to a party of his troops who were to lie in ambush. The sign agreed upon when they were ready for this was that a citizen should come out of the gate of the city and stand upon a certain tomb. Accordingly one day while the Prætor's troops were lying in ambush the man duly appeared standing on the tomb: the party in ambush rose up and rushed to the city, where they found that not only were the gates closed, but a strong party of the besieged army

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was ready to receive them. The fact of a man standing on the tomb was quite accidental; he had no knowledge of the pre-arranged sign. Thus Polybius argues the necessity of having reciprocal signals. He says it was not only necessary in a case of that sort that the man should stand upon the tomb but that there should have been some answer sent from the ambuscade to say that they had seen him, and the man should then have made some additional pre-arranged sign in order to make the thing perfectly clear. I mention this anecdote to show that as a great writer in those times thought it necessary to dwell upon what appears a small matter of that kind, it is a proof of the primitive simplicity of the art.

Telegraphy for many years received the greatest development by war. That has followed of course from the small wants of the civil population. Polybius and those of his time had brought the art to a very considerable extent of perfection. One system was arranged in this way:—At each signalling station they prepared five pieces of wood on which the letters of the alphabet were written in their proper order; five letters on each slip, except the last, which contained four. The station commencing, first shewed two torches as a preparative, and then the message was spelled as follows—torches from one up to five in number, displayed simultaneously on the *left*, denoted the number of the tablet, and then so many on the *right*, the number of the letter on that tablet. The letter delta, would thus be represented by one torch on the left, and four torches on the right, and the letters succeeded each other as each was answered by the other station.

No advance was made on this system for many hundred years afterwards, as I may show by another anecdote. During the wars between the Austrians and the Turks at the close of the 16th century, the latter, after a series of successes, occupied the town of Caniza, and were besieging another town, Olumpagh. The Baron Kiswell, in command of the Austrian troops in the neighbourhood, found the Turks so situated, but was not strong enough to raise the siege, or to break through the Turkish Lines. There was with the Austrian army, one Captain J. Smith, who was a great traveller, and has written an interesting book of travels. He had been on friendly terms with the Governor of the besieged town, and in the course of their acquaintance, the pair had discussed the possibility of Telegraphing by torches, and

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arrange a system between themselves, never dreaming of the purpose to which it was now put. Captain Smith represented to Baron Kiswell that his knowledge might be used to good effect in the service of the Austrian Army; the Baron agreed; and, on a certain night, Smith shewed from a hill top three torches towards the town. After a time these were answered by three other torches on the walls of the town itself. The following messages then passed:—Kiswell to Governor—"On Tuesday night, I will charge on the east of the town: at the alarm, sally you." Governor to Kiswell:—"I will." On the appointed evening the attack was made, and Kiswell was enabled to throw 2,000 men into the town and to relieve it.

As shewing how much advance had been made, the system used may be described. The alphabet was written out in two lines by each party thus:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A | B | C | D | E | &c. .. .. | | L |
| 1 | 1 | 1 | 1 | 1 | &c. | | |
| M | N | O | P | Q | &c. .. .. | | Z |
| 2 | 2 | 2 | 2 | 2 | &c. | | |

The letters in the upper line were each represented by 1 torch: those in the lower line by two torches, and the number of times they were shewn, shewed the number of places from the left, held by the intended letter. The English word "and" would be signified by one torch shewn once, two torches shewn twice, and one torch shewn four times.

In these early days of Telegraphy, it will be noticed that its development was entirely confined to night work. The reasons are obvious: no other object so small as a light is visible an equal distance; and all the motions necessary to carry out a system of successive signs are easy, just in proportion to the size and weight of the objects to be moved. It followed that night telegraphy could be carried on with much less mechanism than that by day, and it consequently took precedence.

A more anomalous condition of things was this:—We have described telegraphy as coming into play when a material body cannot pass with sufficient speed, and you might have expected that the progress would have been much greater always by sea than on land; but the fact was not so. No progress was made by sea for, I will not say decades of centuries, but for many hundred years. Ships were very small, and were able to keep close enough together to

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convey messages by word of mouth. On land, rivers, arms of the sea, rocks, and mountain ranges intervened, and made the necessity for telegraphy more keenly felt than we found it at sea, where all this time there was nothing in the shape of a telegraph but the hanging out of a shield or flag, blowing a trumpet, or shouting with the voice.

So things remained at sea until we come to the reign of Charles the Second in England. It has been commonly said that James, Duke of York, originated the system of flag signals which we have now in our ships. In order to show how erroneous that idea is, I may refer to the Naval Signal Book of 1710. In that book there were about 102 signals. A series of signs of the most arbitrary character, requiring a drawing of the whole ship for their record, and consisting for the most part of variously coloured flags "hung out," as it was termed, in different parts of the ships.

If we are to consider this as a system, perhaps James had something to do with it. But there is here no system, nor does it bear any analogy to that now in use except that both agree in employing coloured flags. As a matter of fact, what James the Second did, was to arrange a system of tactics and a set of instructions for a battle in the fleet, but he made no advance whatever in telegraphy.

Things remained very much in that state till the close of the last century: in fact you may say till the year 1780 there was no such thing as a system of telegraphy by sea. The antiquated arrangements continued, more flags were added and displayed about the ships without order or method. In 1780 however, Kempenfeldt, the gallant officer who lost his life in the Royal George at Spithead, brought the existing arrangements in the navy into something like system. He took the flags then used, and arranged a book with the flags down one side of the margin. At the head of each page stood single flags in their order of occurrence in the margin, and the messages were printed opposite each of the marginal flags. Hence each message came to be designated by two flags, that at the top of the page above that in the margin. As yet it had never struck anybody how much simplicity and advantage would be gained by employing numbered or lettered flags and using them in combinations. As matters went on Lord Howe in 1792 could only make 183 signals to the ships of his fleet; and any ship of his fleet could only make to him some 68 pre-arranged messages.

In or about the year 1799, the flags were numbered for the first

time. The existing flags were taken, with some modifications, and numbered 1, 2, 3, 4, to 0. That immediately opened the door for an increase in the number of signals possible. With ten numbered flags taken 1, 2, and 3 together it was possible to make 810 changes, and to each change might be assigned a separate message. But they had not at that time got so far as this. At the close of last century, in the Royal Navy of England, the Admiral could only make 310 set messages, and private ships could only make to him 80. All this time there was not the slightest preparation for, or attempt to send messages not pre-arranged. That was not done till after the beginning of the present century.

Before showing how we came to arrange for the sending of non-prearranged messages at sea, we must go back to what has been happening on land, because it was the advance of matters on land which drove us—and sometimes still drives us at sea—to make the necessary advances. In 1684 the well-known Hook read a paper before the Royal Society, showing how messages could be conveyed on land to very great distances, by exhibiting in open frames, objects of different forms, each of which represented a number or letter; most of them partook of the nature of a square or circle. M. Amanton, in France, very soon afterwards re-invented the same thing; but neither of these proposals came into practice.

It was war again which brought about the next advance in telegraphy. During the French Revolution, the rapid movements of the French army turned men's minds to some method of conveying messages to and from armies at greater speed than had hitherto been possible. In 1795 M. Chappé invented his semaphore, which was used with such immense effect by the revolutionary army. That semaphore consisted of an upright beam, and a cross beam turning on a pivot. At each end of the cross-beam there are two other cross-beams on pivots; and a very large number of signs could be made by the revolutions of the first cross-beam, in four or five positions, in each of which positions one or both of the second cross-beams could be made to assume four or five others. In that way M. Chappé got an immense number of combinations, and was able to send his messages with considerable rapidity. Shortly after this semaphore became known, many men in England turned their attention to improving it, and producing systems of telegraphy.

Lord George Murray, in 1795, produced his shutter telegraph which

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is this:—He had six shutters, each of which pivoted on a central pivot. When the flat was towards him, the observer saw the shutter, when the edge was presented, it disappeared. The signs were made by exhibiting or concealing a shutter or shutters in succession. In this way he got enough communications to carry out his messages by means of a code. This shutter apparatus, I may mention, was soon after its invention set up between London and Portsmouth, and that was the apparatus which conveyed all messages to and from the Admiralty and the outposts during the last French war. It was set up from Plymouth to London in 1806, and short messages were sent, in from 10 to 12 minutes; while longer messages occupied from 28 to 30 minutes. The advance upon what was practicable before may be understood from the fact that in those days it was generally a three days' journey from London to Plymouth. It was, relatively, just as great an advance in telegraphy as that which was so well described by Mr. Culley at our last meeting, in showing how he got the enormous speed of 120 words per minute to Birmingham.

This advance in telegraphy changed its venue from night work to day. Night had been the most convenient time for sending signals up to this date. The new instrument enabled people to send messages more quickly and more accurately by day, and night telegraphy did not show itself. But this great advance on land turned numerous men at sea to the question whether we could not make an equal advance there? It was a terrible thing that an admiral might be in command of a fleet, and might have the most important message to give, and yet be unable to give it because he was confined to the set messages contained in his book.

In 1801, Admiral Sir Home Popham conceived the idea of making a dictionary, every word of which should be represented by a group of letters, which letters should be represented by corresponding flags. He did this, and the system was introduced into the navy for the first time in Nelson's fleet, with which he fought at Trafalgar. It is not generally known, but it is worthy of remark, that the celebrated telegraphic signal of Nelson before that fight, was given by this system. It not only bore the moral significance then and since attached to it, but it was an experimental trial of one of the greatest advances ever made in sea telegraphy. The two plans described, that of numbered flags in combination, to represent set messages;

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and of lettered flags for messages not prearranged, remain at the present day; all that has been done since is in the way of amplification of detail. While this advance was made by sea in daylight, the state of affairs at sea at night remained exactly the same as they had been in James the Second's time. Lanterns in different numbers and forms, constituted in 1700, 1800, and nearly till 1860, the sole means of telegraphing at night at sea. The plan was singularly defective, and in no degree fulfilled the wants of ships, yet many of the forms of lights in use in the fleet with which James the Second fought the Dutch, continue in use in the navy at the present moment. One particular signal is worth notice. Two lights, one over the other, in Charles the Second's time, was the signal for the fleet to tack. Ever since that time, whenever a fleet has been at sea, it has remained the signal for it to tack, and it is so at this moment. A great number of plans were tried, always without success, not only by the English, but by all other European nations to attempt in some way to bring up the condition of telegraphy by night at sea to that which it had reached by day.

It was not till 10 years ago that Major Bolton on his side, and I on mine, quite unknown to each other, proposed to adapt to lights, the method so well known now to telegraphists, of the dot and the dash, and to use it as a means of telegraphing by night in the army and navy. I need not go into the history of the trials that were made with it. It is enough for me to say that the adoption of the dot and dash has been found in our own navy perfectly efficient. From the moment it was introduced, it never failed to do what was required of it; and at the present instant after having been used in our ships for 8 or 10 years, it is, as far as we can say, more highly thought of, and supplies our wants more completely than ever. Major Bolton and I carried out conjointly a great many experiments with this dot and dash system in order to ascertain at what distances signals could be actually sent. From a station on the Isle of Wight to a steamer at sea we succeeded in getting quite as rapid communication as had ever been got by sea at two miles at a distance of 30 miles. On one occasion in heavy weather from a steamer 15 miles off shore, I sent a message through a station on the Isle of Wight across to Portsmouth to the Commander-in-Chief, and received his answer back in 13 minutes, entirely by the dot and dash system. We were then using the electric light and lime light. Of course powerful lights were necessary to send this distance.

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I have thought it necessary to give you something in the way of an historical sketch of the progress of the telegraph at sea, before I went into the principles. The plans that have come forward and are perpetually coming forward for the improvement of Sea Telegraphy, are very numerous. Those that fail, do so in a great measure because the principles of telegraphy have not been thoroughly understood.

I before mentioned that telegraphy must be carried on by signs, which are either visible or audible. Visible signs may be made distinct by difference in form, in colour, or in the motion of the sign, and these may be used either separately or combined. As examples of telegraphy by form, you may take any of the semaphore class. That of M. Chappé was one purely of form. Motion or time had nothing to do with distinguishing the signs: whether the pauses between the signs were long or short, never interfered with their distinctness. Between every word or sentence the instrument itself was caused to make a certain sign, which separated it from the next word or sentence. In the naval flags we combine distinction of form and distinction of colour. To construct the flags properly, they should in the first place be as different in form from one another as possible: that is, the disposition of the light and dark shades should be as different as possible, and colour should only be brought in as an accessory to distinguish those forms which come very near to one another. In systems of telegraphy by colour alone, I know of only one; that is the system used in the American Navy. The signs are made by small pyrotechnic lights, red, green and white: some are all green, all red, or all white: some lights begin by burning green, and end by burning red: others begin red, and end green, and so on. The number of combinations of these three colours, is sufficient to make as many signs as are required. That system is one of colour alone, and it is the only exclusive colour system that has partially succeeded. A great many others have been tried, and a great many combinations of colours in night signals have also been tried, with little success, or none. Of motion only, we have but the one system, that is, the dot and dash. Of form and motion combined there is only one curious example, the invention of Admiral Bethune, which never succeeded. He used four lights vertically placed, and either showed one or more lights simultaneously, or eclipsed them in succession. Hence the speed at which the changes followed, modified the sign conveyed. The figures 1, 2, 3 were represented by the slow obscurations of th

1st, 2nd, and 3rd lights. When these were quickly obscured, they represented the letter A. Quite recently there has been a combination of colour and motion, brought forward by one of our members, Sir W. Mitchell. He proposes to use red, white, and green light, and to use from 1 to 6 flashes of light of each colour, to represent 18 letters of the alphabet.

Coming now to audible signs, we are confined to two methods of distinguishing them, viz, the motion or time, and the tone. Motion alone is used in the flashing system—of the dot and dash. Sounds, long and short, exactly corresponding to the long and short appearances of the light, are used to make the necessary signs. Of tone alone there is no example, but the ordinary bugle call is really an example of tone and motion combined.

If we turn to our wants at sea, we shall find first that those most prominent are connected with war. Fleets are required to be kept together: the admiral must convey his messages to his fleet, and his ships must be able to say all they wish to him. Again, in case of another naval war the coast of England would require to be studded with stations to enable communication to be held with ships approaching the shore, and passing backwards and forwards to protect them from the enemy's cruisers and to direct fleets passing where the enemy is to be found. No arrangements at present exist for that purpose. In the mercantile marine the question of telegraphy is daily becoming more important than it used to be, again preceded by the telegraph on shore. Stations have been established at different parts along the coast and owners are anxious to transmit orders to their ships and have their ships reported. At present this is done by means of the ordinary flags supplied to merchant ships, and the same used on shore. The range of flags is very small, not more than 2 or 3 miles. To extend the range of such sea telegraphy to 10 or 15 miles, would be a most valuable advance. At night at present there is no method of communication between the shore stations and merchant ships, and this also remains to be supplied. The laying of electric cables has brought into close connection with itself the system of telegraphy at sea. When the Great Eastern was picking up and laying the last two successful cables, there was enormous use made of the system of flags and the flashing system which I have mentioned. I have here the original records of the signals that were made, and I think it will not be out of the way, if

I read two or three of them, as showing what is required to be done by sea telegraphy in the every day work of the telegraph engineer.

I first come to the 16th August, 1866, 9.30 p.m.—Eastern to Terrible—"Will you come as close as possible to the buoy; we have a very heavy strain on, and are very near buoy. Please try to keep light up." Aug. 17th, 12.5 a.m.—Medway to Eastern—"Are you lifting cable?" A. "No; will wait day-break." Then we have later, such messages as "strain 9 to 10 tons—hooked cable." "Get here as quick as possible." "Hurry up." "Have hooked cable 1,901 fathoms out, 10¼ tons strain." "You have hooked buoy; you cannot have hooked cable on your bearings." "One hook of grapnel had cable; slipped up as you hove up." "We must wait one more calm opportunity, otherwise would spoil all;" and so the record goes on with varying expressions of hope and fear, until on the 2nd of September, I find at 3.30 a.m.—Eastern to Squadron—"Cable all right, send immediately all hands on board," and I find that the spliced bight was slipped for its work at the bottom of the sea at 7.0 a.m.

Now there are two wants that have to be fulfilled in sea telegraphy. One is to enable you to address a great number of points at the same time, the other is to address a single point as rapidly as possible. In electric telegraphy, the business is carried on in the stillness and quiet of an office; while at sea the most important messages must be sent when everything is so to speak topsyturvy. No method can be successful at sea which does not recognize this difference in the conditions.

Signs to be visible must be of great size, and consequently have to follow in very slow succession. From that it comes that we are obliged to use the code. What we want to do is to limit, as much as possible, the number of signs to be transmitted. In consequence we prepare Codes in which the words, sentences, reports, or orders in common use are represented by a very much smaller number of signs than their component letters. These signs are then represented to the eye or ear by forms, colours, or motions. By semaphoric symbols, by the shapes and colours of flags, and by the dot and dash. The growth of codes was originally natural, and had little claim to any underlying principles such as they now possess. The few original simple signals, to advance, retreat or perform such other movements, gradually accumulated, and required to be noted

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in a book. As they were added to, the book grew larger, and at last changed its character in assuming its modern systematic development. The value of the code is due entirely to the increased speed it gives to sea telegraphy, and if a speed in spelling, equal to about 30 words per minute were now possible in general service, the use of codes would soon become obsolete. To quote an exception which proves the rule, I may mention that some ships now use in the day time small semaphores—of the kind devised by the late Sir C. Pasley —from ship to ship at short distances, these instruments are capable of sending between 20 and 30 words per minute, and in such cases the code is not used. This would be the case also when great practice is kept up with the flashing system.

The existing English codes are, first, the naval codes; then we have the International code, a most useful and valuable thing, used in every merchant ship, and adopted by nearly every European nation, so that ships of each nation may communicate one with another; lastly, there is the army and navy code, for the joint use of both services. But there is one point which we are sadly deficient in as yet. That is, that many nations have different kinds of flags—many different signs to represent the same letters or figures. If we could get established at sea a universal flag alphabet between all nations, half the difficulties would at once pass away; but I suppose that is next to hopeless.

Time does not permit me to do more now than to offer a brief description of the apparatuses in use in England for telegraphing by sea. In the Royal Navy we have, first, the system of coloured flags, in which the colours are red, yellow, blue, black, and white. Distinction is gained, first, by the shape of the flags themselves, some being long and taper, others triangular, others nearly square. Next, by the disposition of the light and dark colours on each flag, and lastly to a small extent by the differences of colour alone. These flags either represent letters or figures, or have some special uses attached to them. They are displayed either singly, or in groups of from two to four. In all cases the groups are read from above downwards, as printed letters or figures are read from left to right. These flags are supplemented by the semaphores before mentioned, and also, but only as yet to a very small extent in the day time, by the dot and the dash of the flashing system. The most efficient instrument for this purpose is a collapsing drum, which closes towards its central hoop, and whose open state for long or short periods represents the dots and dashes, and its

closed state the intervals. It was with such an instrument that most of the day telegraphing between the Great Eastern and her consorts when laying the Atlantic Cable was carried on. The raising and lowering of a flag for varying periods of time—the waving through long and short arcs of a flag on a staff, are also very efficient means of signalling.

At night in the navy, the mainstay and universal method of telegraphing is the flashing system. The instrument in use is of uniform pattern throughout the service, and consists of an oil lantern capable of displaying its light over an arc of 180° horizontally and to a distance not exceeding six miles in clear weather. The motion of a vertical shade exposes and conceals the light which can be displayed from any part of the gunwale. Height is not required, as the range of the light is considerably within that given by the curvature of the earth. The vertical shade can be worked either by hand or by an instrument very much on the principle of the barrel organ, which can be set to any required signal and turned continuously by means of a handle. The result is that accurately measured signals can be kept displayed for long periods of time. At present—it is proper to state—this instrument is very little used, the signals being in preference made by hand.

During fog in fleets, a limited number of signals are conveyed by means of guns fired at varying intervals, and when the distance will admit, steam whistles, and fog horns are used to produce long and short sounds corresponding to dots and dashes. It is the happy peculiarity of the flashing system, that it adapts itself to all circumstances, and these fog signals answer so well at short distances that endeavours are constantly being made to extend the range of present sounding instruments.

The Mercantile Marine uses coloured flags in the day time in a manner similar to that existing in the Royal Navy, but as yet it has no means of telegraphing either at night or in fogs. It has not yet employed, and does not understand the simplicity and value of the flashing system—the prevailing impression being, that it is something too abstruse for ordinary comprehension, instead of a system whereby any one who can read and write may become an accomplished telegraphist after two hours instruction. It is not generally comprehended that the success of a system of sea telegraphy depends mainly on its range: that is, on the distance at which its signs are legible in

the ordinary conditions of sea service. In the Mercantile Marine this is an especially marked requirement, for the chief use made of its telegraph is communication with the shore—reporting to electric telegraph stations on the coast line. Range is obviously all-important here, and most important at night; for no ships can be legitimately called on to approach shoal water for the purpose of telegraphing. In order to obtain this range, Major Bolton and I, some years back, designed the light known as the Chatham Light. In appearance it is similar to the ordinary oil light, and can be—and is now in the flag-ship of the Channel Squadron—substituted for it when the distance or state of the weather makes a stronger light necessary. The flashes, which are extremely brilliant and are visible at least twelve miles, are produced by blowing finely powdered magnesium diluted with a resinous substance into the flame of a spirit lamp. Some difficulty has been experienced with the light in consequence of a tendency of the tubes projecting the powder to become choked. That, however, has now been obviated, I believe, completely. The lamp and necessary apparatus is extremely simple and inexpensive, and the cost of an ordinary signal from a merchant ship to a station 10 or 12 miles off will not be more than two-pence. Hence I am led to believe that such a light will ultimately be found to fulfil the wants of the Mercantile Marine in telegraphing at sea.

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## REPORT OF DISCUSSION ON CAPT. COLOMB'S PAPER, AT ORDINARY MEETING OF S. T. E., 27TH MARCH, 1872.

THE PRESIDENT thought Capt. Colomb need make no apologies for his communication; and before he proposed a vote of thanks, he would invite members present to make observations, either by way of question or remark, on the subject that had been so well brought before them this evening.

Capt. WEBBER said, he thought they were very fortunate, that at one of the early meetings of the Society a Member of Council should have given them so much of what might be called the early history of telegraphy. There might be said to be one advantage in it—that was, that in future papers, authors would probably refrain on commencing in a similar manner. A great deal of what was

written was made up of history, but they had had much that was new to them to-night from Capt. Colomb, which, added to what they could read in published works, might well be allowed to dismiss that subject in future from the papers which would be read before the society. The subject might also be considered an appropriate one, because Capt. Colomb had dealt with that part of telegraphy which preceded the branch of the science which was best known to most of the members, viz., electric telegraphy. Capt. Colomb had shown how a great deal of the history of it was connected with military history in the events of past years, and he went on to show that it was more lately introduced in the navy for the purposes of signalling at sea, and that from time to time it was dropped and taken up again for military purposes, whereas from the date of its infancy for naval purposes it had been kept going and had been improved. The reason might simply be given that in the navy it was used in time of peace as well as in time of war, whereas in the army there was nothing to stir up the soldier except when the real business of his trade began. Of course in the present day, when there was so much talk about military improvements, they might look for the appliance of science to the art of war in time of peace; but the effect of the system adopted for naval and military service had been this—that the navy had formed a code, they had adopted that code to their own wants, and it was not until Captain Colomb and Major Bolton came together in the way described, that it became evident that one code would have to be formed which would be adapted to both services. The consequence was that in this case, although the army had been before in advance of the navy, the former was now obliged to follow the lead the latter had given, and adapt itself to the wants of the navy. He did not say that what had been adopted was not the best that could have been adopted, but it was right to point out, as Captain Colomb had dealt with the subject of telegraphy on land, it did not necessarily follow that the use of the naval code was the best for land purposes. This subject would again be treated of in a future paper to be read before this Society, and therefore he only wished that the gentleman who would read that paper would take for his text what he had said—that the army had to follow the lead of the navy, and the circumstances and wants of sea visual signalling had been made subordinate to the wants of land visual signalling. He would like to ask Captain Colomb why he would give up the use of the code

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if, as he had said, he was able to signal by other means at the rate of 30 words a minute? He thought that on this turned a good deal of what he had been suggesting, and he would also venture a suggestion in reply to a wish which Captain Colomb expressed, that it would be a good thing if there was an universal alphabet which all nations would understand—one which had doubtless occurred to the minds of many present, to say that they had a universal alphabet in the Morse alphabet. Again, Captain Colomb said it was a desirable thing to place a more powerful light than they now used in the copper lamps, though in the merchant service paraffine lamps have long been used for ships lights. Paraffine was not allowed to be carried on board the ships of the Royal Navy; there was no question that paraffine was easily managed in a lamp constructed to prevent smoking in a high wind, and the penetrating power of the light was three times that of ordinary oil lamps used in ships.

In relation to telegraphy at sea, one system had been brought before the public in a modified way, which had not been mentioned to-night by Capt. Colomb. It had been attempted at several places, and no doubt gentlemen present might be able to offer some remarks upon it; that was the establishment of Channel stations either in mid-channel or at some distance off the coast to communicate with the land. He had heard something about it, and he knew a little about the attempts to establish these mid-channel stations. He thought the abandonment of one attempt last year was, he would not say precipitate, but he thought it was a pity more experience was not gained in connection with that attempt, viz., the anchoring of a ship near the Lizard, and having a cable from it to the land to signal vessels coming up Channel. This might be included in the systems of telegraphy at sea, and it was a subject on which he would suggest some member might be able to give them a short paper on a future occasion.

Mr. Moore said he had no intention of addressing the meeting, but was induced to do so from the remarks of the gallant gentleman who had just sat down, who wanted to know something about telegraphy from a vessel in mid-channel, or other part to the shore; and as he (Mr. Moore) had had something like 23 years thought and experience on the subject, he begged to say that a company was formed to carry out his invention in 1863, which failed for want of funds. When Mr. Alfred Brett was laying down his submarine cable from Dover to Calais, he had a great many conversations with that

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gentleman as to the means of communication from any of the light-ships in the Channel to the shore, as a means of saving life in cases of shipwreck; that vessels in distress, instead of firing guns might communicate by submarine wire. Mr. Brett said it could not be done, others said it could. He (Mr. Moore) tried some experiments, and failed. The late Prince Consort afterwards introduced the subject to the Trinity Board, through Mr. Dilke, and they failed, because they did not hit upon the right mode. In 1862 he had a vessel placed down Channel, and after some experiments found the right way of swinging a ship, so that she might swing to her head. If the vessel had been stationed up Scilly last year, which was proposed 30 years before the lightship was placed there, if they had adopted the proper system, he believed that vessel would still have been at her station, and they would have had the means of communicating from that ship to the shore. As Capt. Colomb had said they could not at present get any above-board signals through fogs, and snows and rains, and therefore if they wanted to get signals at a distance from the shore it must be done by electricity, and the only way of doing that was by submarine wires.

Captain DAWSON, R.N., said he was sent, on one occasion, to investigate and report upon a system of telegraphy at sea, the inventor of which claimed this special qualification—that he was not aware of any of the existing systems; and that, therefore his mind being clear, he must have special qualifications for understanding all about the subject. That certainly was a qualification which his friend Captain Colomb did not possess, because for many years he had devoted his attention almost exclusively to this subject, which had made himself an authority upon it having had more practical experience in it than any other officer in the navy. He (Captain Dawson) sympathised with his brother officer of the sister service, in his feelings that it was not agreeable to be dragged after the navy in matters of this kind; but the fact was that, whereas telegraphy was only occasionally needed in the army, the navy could not exist a day without the means of communicating by visual signs. It was part of their vital breath. In his boyhood he learnt the daily use of these flags under different names, and they were so engrafted upon his mind mind that he had never learnt the new names. Captain Colomb had truly stated that they were better able to signal to long distances by night than by day. They were still unfortunately limited to an area

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of two or three miles by flags by day, particularly when the weather was calm, because the flags hung down. There was great room for invention and improvement in this direction. As to the suggestion made by the last speaker, that in time of war we should anchor ships off the coast for signalling purposes, it was rather amusing. He did not know what an enemy would think about it, but he apprehended they would either be sunk or carried off. The system of dots and dashes was capable of almost infinite expansion so as to be used in various ways. It was especially applicable to the steam whistle, and intelligible communications might be made by short or long sounds at sea both by night and day. Coloured lights had been tested in a great variety of forms, but had always failed, yet they were constantly being brought forward as something which had not been tried before. Captain Colomb had exhausted the subject by practical experiments carried on for many years, and had placed on record elsewhere most valuable data as the result of accumulated experiments; in describing what had been done, Captain Colomb had done so without pushing his own inventions prominently forward Those flashing signals which had been described to-night were now in constant use in the navy, and were used all over the world every night whilst they were sleeping in their beds. The fleet had had large experience of their practical working, and they appeared so far to answer all the purposes that they required at sea.

Mr. Moore (in explanation) said in time of war it would be easy to place a vessel of war (which could maintain her own) as the station from which communications could be made with the shore.

Mr. W. H. Clapp, in reference to Captain Colomb's allusion to Sir William Mitchell's system of signalling by colored lights, begged to state that three years ago (March 11th, 1869) he patented an apparatus for communicating signals by means of colored lights adapted for the mercantile marine. He also constructed a code representing the 18 letters of the alphabet used in the code of commercial signalling; whereas Sir William Mitchell's patent was dated May, 1871, two years after his, (Mr. Clapp's). His invention was, however, at the time pronounced to be too complicated and he had abandoned it, but retained the code in its integrity, and had laid it before the Trinity House and the Board of Trade.

The President said—They could not go into the question of priority of invention.

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Mr. CLAPP had listened to Captain Colomb's remarks with great satisfaction, and quite agreed with him that a system to be of use must be universal. He had studied the subject for many years, and was still pursuing it, and he felt he had gained great advantage from attending the meetings of this Society as one of its members. He hoped at a future time, to lay before them the results of some o his investigations into this subject.

Sir CHARLES T. BRIGHT remarked that they were much indebted to Captain Colomb for his description of the excellent system of signalling introduced by him and Major Bolton for the use of the naval and military services. He was not before aware that the system of signalling had arrived at so complete a state of organisation as he found it to be from the paper and from the apparatus before them; and, though he had been a good deal at sea in ships of the navy, he was not aware that the system was in general use. He should be glad to hear that it was so. His impression had been that it was only used in the flag-ships of fleets, and by the staffs of military commanders; and, if so, its utility was restricted in a manner it ought not to be. He thought pressure should be brought upon the Government to use the system of signalling more extensively. Signalling by lights was not a new idea, but the perfection to which it had been brought by Captain Colomb and Major Bolton did great credit to those gentlemen. He supposed it was the earliest system of signalling to signal by flashes of light. It was done by the American Indians on the prairies by means of pieces of glass and the rays of the sun. The system of flashes of light was that which he used in laying the first cable in the Persian Gulf in 1863. That was after Captain Colomb and Major Bolton had taken up the subject. He believed he got the suggestion either from Mr. Laws or Mr. Whitehouse. He used it between the ships by means of lanterns, not so powerful as those exhibited here. The light was obscured by a movable handle, and by that means he was enabled to telegraph to every ship he had to communicate with, and it proved to be effective at distances at from 3 to 5 miles. By means of those signals there was a saving of a great many men and boats in going with messages to and from the vessels in boats. In the day time the signals were made by discs, moved by the hand by a lever. He should mention that the cables were laid by steamers towing sailing vessels, and the same system of telegraphing was used between the towing ships and the others by night and b

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day. He had been aboard ships of the United States Navy, and he noticed that they employed the slow and tedious process of semaphoric signals by the movement of men's arms. With the system of lights they ought, under ordinary circumstances, to be able to signal at the rate of 30 words per minute. They could read 20 words per minute in the Persian Gulf with the dot and dash system.

The PRESIDENT announced that the time for adjournment had arrived; but the subject was one of so much interest, that he wished to give an opportunity to those who wished to do so, to make observations upon it at the next meeting, previous to the reading of the paper appointed for that evening.

Captain COLOMB begged to inform Sir Charles Bright that so far from pressure upon the Government being required, the system of signalling he had described was in use in every one of Her Majesty's ships at the present moment.

The meeting then adjourned.

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The Fourth Ordinary General Meeting was held on April 10th, 1872, C. W. SIEMENS, Esq., President, in the Chair.

Capt. COLOMB, in reply upon the discussion on his Paper on Signalling at Sea, read at the previous meeting, said there were only two or three important points which arose in the discussion to which he proposed to address himself. The first was raised by Captain Webber, who asked why not, in sea signalling, give up the use of codes and send the messages alphabetically, as messages were sent through wires on the land? One of the chief reasons why the code could not be given up in sea telegraphy was the necessity which existed for addressing a very large number of points at the same moment. It was better to say on that subject that the thing had been accurately tested; it had been tried in a great variety of ways, and it had been found that unless a speed of telegraphy by sea could be attained as great as 30 words per minute, the use of the code was essential. As a matter of fact, they had not yet arrived at a speed, under ordinary conditions at sea, greater than four or five words per minute. The next point was why not make the Morse alphabet

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universal? instead of using, as they did at sea, a simple method of employing the ten figures when the dots correspond to the figures from 1 up to 5, 6 being a dash; 7 a dot, followed by a dash; 8 a dash, followed by a dot; 9 two dots, followed by a dash; and 0 a dash, followed by two dots. The reason why they could not employ the Morse alphabet was because in sea telegraphy, unlike telegraphy on land, they could never secure constant practice, which was absolutely necessary with the Morse alphabet, involving an immense number of different signs. It had been tried most thoroughly by his friend Major Bolton and himself, and they had found in telegraphy by means of light at sea, operators who had been perfectly efficient three or four months before with the Morse alphabet, failed to reach the same speed that perfectly untutored boys reached with the simpler arrangement of flashes and the code. A very important matter in connection with this subject was that the use of sea telegraphy was always occasional: it was required at the most unexpected moment, and without any preparation; and one of the most important functions was the putting the combined forces of this country, the army and navy, in communication in the operations of war; therefore if they had anything but the very simplest arrangement between those two services, called upon to put themselves in communication by the telegraph or signal unexpectedly, they were nearly sure to break down. That also had been put accurately to the test. Another point raised by Capt. Webber, was the use of paraffin or the light intended to be employed on board ship. The objection to the use of paraffin was, first, its danger. Paraffin such as could be profitably employed in lamps, gave off inflammable vapour at a temperature of 140°, and that temperature was often reached in ships, especially in steamers, and they never could calculate on having the temperature of the paraffin below that point. Again, no paraffin lamp had yet been produced, capable of giving sufficient light, without a chimney; and the chimney was very soon broken and destroyed in the rough usage these things receive on board ship, and also on shore in the operations of war.

Sir Charles Bright raised a question which he thought he (Captain Colomb) ought to touch upon, though, he took it, in this Society, they never dealt with questions of priority of invention; but he would say on behalf of Major Bolton and himself, that their originality in introducing the system of the dots and flashes into the army and navy

was infinitesimal. They had used a great deal that was done before and they had used very little that had originated in their own minds As Sir Charles Bright said, the idea of using flashes of light and disappearances of objects as a means of visual telegraphy was as old as the hills. All Major Bolton and himself had done, had simply been that before they made public their principles, they had tried, themselves, a sufficient number of experiments to be perfectly certain that they were right, and consequently they were able to overcome the inertia which always hung over the introduction of new things: they were able to overcome it so far as to see that the Morse dot and dash in use as the best means that ever had existed of telegraphing at sea.

On the motion of the President, a vote of thanks to Captain Colomb for his paper was unanimously agreed to.

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# ABSTRACTS AND EXTRACTS.

## NAUTICAL TELEGRAPHY.

By Capt. Colomb.

The following appears in the February number of the *Reveue Maritime et Coloniale*:—

Everyone knows that since the organization of Electro-Semaphores on our coasts, every Captain of a ship, whatever be his nationality, who wishes to signal to his owner his passage, or the leading events of his voyage can do so by the aid of the International Code. His messages are then translated and forwarded by the Electric Telegraph to their destination by our Look-out-men. These messages have hitherto been subjected to a tariff. Now the transmission is gratuitous, at least for messages addressed to the Chamber of Commerce at Havre.

This Chamber has made arrangements with the Ministers of the Interior and of Marine, by which, from and after the 1st January, 1872, the Semaphore Stations of Fécamp, Barflour, Ushant (s.) and Point d'Argie (Belle-isle), will transmit to it twice a day a list of vessels whose names are made out on their passing in view of the Semaphore. The exchange of the necessary signals will be made gratuitously for the Captain as well as for the owner. The telegrams are sent into office by the Look-out-men at 10 a.m. and at 3.30 p.m., and are posted at Havre as soon as they arrive, and placed at the disposition of those interested.

Such a measure (says the *Reveue*), cannot fail to draw the attention of our Chambers of Commerce, and notably those of Nantes, Bordeaux, and Marseilles. The result will be a considerable increase of convenience to our Maritime Commerce, and the numerous interests which it developes.

## ON A NEW TELEGRAPH WIRE GAUGE.

By H. Mallock and W. H. Preece.

In purchasing iron wire it has hitherto been the invariable custom to specify its size, according to the Birmingham gauge. This wire gauge varies with every manufacturer, and there is, not only no standard from which he can correct his own, but no one is aware on what basis the gauge was originally made, so that

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it is impossible to reproduce it in any correct shape. Mr. Culley in a note to table (No. 9), in his handbook says, "Birmingham Wire Gauge.—The diameters of the several gauges must be considered approximate only. There is no authorized standard, and the sizes of different makers vary considerably."

Mr. Latimer Clark's paper read before the British Association in September, 1867, so well describes the variations of different makers, that it is useless to bring forth any further proof of its inconsistency and its self-evident inconvenience. It is evident that in establishing any gauge, it should have been coherent throughout. It should have been based on a regular increasing series, and should have started from some recognized and well-known unit. Mr. Latimer Clark has pointed out the probability that the present Birmingham Wire Gauge originated from No. 16 Bell wire as unit, that wire being 1-16th of an inch in diameter; but this is a mere arbitrary size to select, and although it may be understood that before Telegraphs were in existence, Bellhangers would start from a size most convenient to them, that size bears no relation to any telegraphic purpose, and it bears no relation whatever to the remainder of the series.

Mr. Whitworth suggested that we should adopt the decimal part of an inch as the unit, and establish a gauge based upon regular increments of size in thousandths of an inch; but this again bears no direct relation to the weight and resistance of the wire—two points which are of paramount importance in dealing with wire for electrical purposes.

Mr. Latimer Clark proposed to establish a gauge starting from the No. 16 wire as a unit, and increasing or decreasing by regular increments or decrements of 25 per cent. of the circular area or weight of the wire. But this system again has no relation to the physical qualities of the wire, and cannot be said to be *absolute*. We want a system based upon the fundamental units of measurement, either of mass or of length.

The question, therefore, arises whether in establishing a uniform and coherent gauge for iron wire, it should be based upon weight or upon diameter.

In favour of a gauge based upon weight, it must be remembered that we already purchase wire from the manufacturers, transport it, pay for its transport, and distribute it along the lines upon which it is intended to be erected, by weight.

Its breaking strain is in direct proportion to its weight. Its capacity for the transmission of messages depends upon its resistance, which varies with the square of its diameter, and therefore with its weight; and we test and regulate our circuits in terms of resistance (that is weight), and not in terms of diameters, or the square roots of weights.

Finally, as weight is invariable in all temperatures and latitudes, a size dependent upon a number of lbs. per mile, will be constant, as long as lbs. and miles exist. And by adopting these units as a basis, we have a ready means of correcting our gauge at all times.

Weight of wire at once gives us an idea of its resistance, and in the case of stranded wire this information is essential, for otherwise, even when the diameters of each separate wire is taken, an approximate correction has to be made for the lay of the strand.

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On the other hand, it must be noted that the adoption of a system dependent upon weight necessitates a separate gauge for wire of each metal, whereas a gauge of diameters would do for wire of all metals. We are not aware of any inconvenience that is likely to arise from this cause. The measurement by diameters must still remain for ordinary use, whatever species of gauge be used, and resistance in absolute units already gives us a system which connects together all wires, however they may be gauged, purchased, or used. Yet the practice at present is invariably to specify and to purchase copper wire for cables by weight, and the application of the Birmingham wire gauge to the dimensions of copper wire is rapidly falling into disuse, and copper wire is either designated by its weight per knot, or by its diameter in thousandths of an inch; and there is therefore a precedent for adopting the same system for iron wire.

It may be said that the verification of wires purchased by weight, is more difficult than that purchased by a decimal gauge; but there can be no mistake about its being more accurate, for when measuring the diameter of a wire in thousandths of an inch, but one or two minute places are measured, and from rough galvanizing or other such cause an error can be easily made, whereas in weighing the 1-1,000th part of a mile (or other convenient length), the average weight of the whole will be much more correctly approximated.

On the other hand, in favour of a gauge dependant on diameter, it is evident that one gauge will do for any material used for wire either for land lines, submarine cables, resistances, or apparatus.

Again, the gauge by weight is a difficult thing to test or verify anywhere except in stores; whereas any one can carry in his pocket a wire gauge, to verify the dimensions. On the other hand, dimensions check weight, and it would be very convenient to be able to tell at once the weight of wire by merely taking its diameter. This can be done at present, but only by the use of co-efficients which are difficult to remember.

It appears, therefore, upon the careful consideration of all these reasons for and against adopting a gauge dependant upon the weight, that those in favour of such a system are insurmountable.

It therefore remains to determine from what unit we shall start to establish a gauge dependent on weight. The pound is evidently the natural unit, but iron wire weighing one pound per mile is smaller than anything used for telegraphic purposes, and if we only increased by increments of a pound, the numbers of wires would become too numerous. We must therefore find some multiple of this natural unit that will give us a series approaching the sizes of the wires at present in use as closely as possible.

It has been mentioned above that Mr. Latimer Clark proposed to adopt No. 16 Bell wire as unit to start from; and by regular increments and decrements of 25 per cent. to the weight of this wire to establish a series which would be found to approximate very closely to the Birmingham wire gauges at present in use, and which might be substituted for them without much inconvenience. We find, however, that by taking 25 times the natural unit, or 25 lbs. weight per mile and unit, and increasing by regular increments of 25 lbs. we establish a regular ascending series much more closely approaching the average wire

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gauge at present in use than that proposed by Mr. Clark; and also when the diameters are worked out, very closely approaching what Mr. Whitworth proposed.

Tables are annexed giving the present Birmingham wire gauges according to Messrs. Johnson and Mr. Latimer Clark, and that which is proposed by us. It will be seen, on an examination of this table, that the diameters and weights vary but very little from those at present in use. While one or two of the wires more commonly employed are lightened, others are increased, but by so trifling an amount that no material difference can be experienced.

It is intended, in adopting this gauge, to weigh the wire on its receipt from the makers; but to use a gauge of diameters similar to that now in use for general use on the lines. As the size would be checked by weight on purchase a trifling inaccuracy in the diameter gauge would be immaterial in practice, as with the proposed differences between the sizes one size could not be mistaken for another.

By carefully determining the resistance of a wire weighing 25 lbs. per mile at a given temperature, the resistance of any other wire at the same temperature is found by simply dividing that resistance by the number representing the size of the wire— that is if the nomenclature proposed in the table be adopted.

Similarly the breaking strain of No. 1 wire weighing 25 lbs. per mile, being known the breaking strain of any other size will be determined by multiplying its number by that breaking strain.

In many lines, both in India and in England, the wires are mixed. For instance, in India the sizes of the wires vary with the numbers on the posts as they approach the large stations, as illustrated by the following:—From Calcutta to Raneegunge the two main wires are made up nearly as follows:—viz., two miles of No. 12½, weighing 150 lbs. per mile; 14 miles of No. 9½, weighing 300 lbs. per mile; 60 miles of No. 5½, weighing 600 lbs. per mile; 100 miles of No. 1 wire, weighing 1,200 lbs. per mile. A man by the weight system in testing, knows at once that he has to look out for a resistance $= \{(2 \times 8) + (14 \times 4) + (60 \times 2) + 100\}$ of the resistance of No. 1, whereas, had there been Nos. 8, 4, and 1, instead of using simple factors which are necessarily in his head, he would have to use broken numbers as factors. It must be noted that the Indian Telegraph Department abandoned the B.W.G. in 1864, and adopted for their lines, made since that time, sizes in multiples of 75 lbs. per mile.

It now remains to be determined how we shall denominate these gauges; whether we shall adhere to the present nomenclature determined by the Birmingham wire gauge—whereby the proposed sizes of wire will retain their present names—or whether we shall introduce a fresh series of numbers starting from our unit 25 lbs per mile as No. 1, and calling all others by their multiple of that number.

The latter arrangement would at once give a definite idea of the weight, and therefore of the resistance, of any wire, without having to carry several tables in one's head. It will be seen that the tables also contain the new numbers which are proposed.

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## COMPARISON OF WIRE GAUGES.

| B.W.G. | Proposed Telegraph Gauge. | | | B.W.G. according to Johnson. | | B.W.G. according to Latimer Clark. | | Whitworth's Standard Decimal Measure. | | Latimer Clark's proposed Gauges. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gauge | Wgt. | Dia. | Wgt. | Dia. | Wgt. | Dia. | Wgt. | Dia. | Wgt. | Dia. |
| No. 1 ... | 48 | 1,200 | 294 | 1,245 | 300 | 1,210 | 300 | | 300 | | 346·5 |
| ,, 2 ... | 42 | 1,050 | 275 | 1,117 | 284 | 1,054 | 280 | | 280 | | 309·9 |
| ,, 3 ... | 36 | 900 | 255 | 928 | 259 | 909 | 260 | | 260 | | 277·2 |
| ,, 4 ... | 30 | 750 | 232 | 783 | 239 | 775 | 240 | | 240 | | 247·9 |
| ,, 5 ... | 27 | 675 | 220 | 670 | 220 | 651 | 220 | | 220 | | 221·7 |
| ,, 5½ ... | 24 | 600 | 208 | | | | | | | | |
| ,, 6 ... | 21 | 525 | 195 | 570 | 203 | 538 | 200 | | 200 | | 193·8 |
| ,, 7 ... | 18 | 450 | 180 | 448 | 180 | 461 | 185 | | 180 | | 177·4 |
| 8 ... | 15 | 375 | 164 | 376 | 165 | 389 | 170 | | 165 | | 158·7 |
| 9 ... | 12 | 300 | 147 | 303 | 148 | 323 | 155 | | 150 | | 141·9 |
| ,, 10 ... | 10 | 250 | 134 | 249 | 134 | 264 | 140 | | 135 | | 126·9 |
| ,, 11 ... | 8 | 200 | 120 | 199 | 120 | 211 | 125 | | 120 | | 113·5 |
| ,, 12 ... | 6 | 150 | 104 | 164 | 109 | 163 | 110 | | 110 | | 101·5 |
| ,, 13 ... | 5 | 125 | 95 | 124 | 95 | 124 | 95 | | 95 | | 90·5 |
| ,, 14 ... | 4 | 100 | 85 | 95 | 83 | 97 | 85 | | 85 | | 80·3 |
| ,, 15 ... | 3 | 75 | 73 | 72 | 72 | 76 | 75 | | 70 | | 72·6 |
| ,, 16 ... | 2 | 50 | 60 | 58 | 65 | 57 | 65 | | 65 | | 65·0 |
| ,, 17 ... | | | | 44 | 57 | 46.3 | 58 | | 60 | | 58·1 |
| ,, 18 ... | | | | 34 | 50 | 33 | 49 | | 50 | | 52·0 |
| ,, 19 ... | 1 | 25 | 42 | 27 | 45 | 24 | 42 | | 40 | | 46·5 |

The diameters are given in thousandths of an inch.

N.B.—Should experience demand an intermediate size between 25 and 50 lbs., a size called 1½, weighing 37½ lbs. per mile, would supply the want; numbers 60, 80, and 100 would also give the large sizes for cable making.

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## ELECTRICAL APPARATUS FOR CONTROLLING THE SERVICE OF WATCHMEN, AND OF NIGHT GUARDIANS.

By H. Cauderay, Inspector of the Western Swiss Railway Telegraph at Lausanne.

The apparatus hitherto used for recording the passage of night watchmen, and others engaged in the onerous duty of exercising a nightly surveillance over a building or any place whatever, have usually failed for many reasons. Having

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had the looking after of several of these machines, M. Cauderay finds that the following are the most frequent causes of failure:—

1. Several times the instrument carried by the men has been dropped, and consequently damaged accidentally, according to the statement of the men; a fact difficult to prove.

2. Dishonest employés find means of opening the apparatus by false keys, or other things, and so to make the marks in the interior as a proof of their having gone their rounds.

3. The chains holding the keys have been cut and damaged, and carried off, so that the night watchman could enjoy a little more sleep.

4. These keys frequently disappear in the most mysterious manner.

5. The heaviness of the apparatus, and the difficulty from cold of using the keys, are complaints made by the watchmen themselves.

The forms of apparatus spoken of are somewhat similar, one may be taken as a type, that invented by Schwilgué of Strasburg, being a "portable marker." This instrument consists of clockwork, which put in motion a paper dial disc, making one complete revolution every 12 hours. The disc can be replaced daily. The whole is enclosed in a case which has on one side a series of key-holes of various shapes and sizes, and for each of which there is a special key; the keys are fixed to the end of a chain attached firmly to certain points in the building, which the watchman has to visit. The watchman carrying this apparatus arrives at one of these points, he inserts the key in its proper hole and turns it round, the key presses against a lever which has at its end a point, this point perforates the disc at a certain definite hour. The disc being examined in the morning shows whether all the stations have been visited, and the hours of the visits.

To meet the various difficulties of the case, M. Cauderay has designed an apparatus to which the active power of electricity has been applied. The following is a brief description of the apparatus:—

A disc of paper divided into twelve hours is set in movement by clockwork, and advances regularly, as would the hands of a clock. A certain number of electro-magnets are arranged in a semi-circle in front of the disc—as many electro-magnets being fixed as stations required—the armatures have at their extremities a "pricker," and are so arranged that all these prickers are in the same line. Each electro-magnet is in connection with a button or key placed where convenient in the building, and at certain special points which the watchman has to visit. A small battery only is necessary.

In making their rounds, the watchmen press the electric contacts, the electro-magnet is excited in the closing of the circuit, and the annature, on being attracted, "pricks" a hole in the paper disc at the same time; station after station is visited, and the paper disc shows a faithful record, not only of the visit, but of the exact time.

Since an apparatus of this kind has been fixed at a Penitentiary at Lausanne it has not ceased to work most regularly; it is placed in the Directors' room, and he has now become so used to it that he can tell within a short distance the place where the watchman should be, and, in case of a wish or requirement

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to send any special orders, a glance at the disc would at once let him know where to find the required man.

It is very necessary that in certain places some sort of apparatus should be used, so as to exercise a control over the movements of watchmen and others who are required to keep guard over valuable property, and several plans have been in use. The Continental plan of carrying an instrument about is most cumbrous and unreliable, and those who are obliged to keep some check upon the somnolency of their watchmen will welcome this apparatus as very desirable.

G. E. PREECE.

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## ON THE INDUCTION OF ELECTRIC CURRENTS IN AN INFINITE PLANE SHEET OF UNIFORMLY CONDUCTING MATTER.

By Prof. CLERK MAXWELL, F.R.S.

THE currents are supposed to be induced in the sheet by the variation in position or intensity of any system of magnets or electro-magnets.

When any system of currents is excited in the sheet, and then left to itself, it gradually decays, on account of the resistance of the sheet. At any point on the positive side of the sheet, the electro-magnetic action is precisely the same as if the sheet with its currents, retaining their original intensity had been carried away in the negative direction with a constant velocity R, where R is the value in an electro-magnetic measure, of the resistance of a rectangular portion of the sheet, of length 1 and breadth $2\pi$. This velocity, for a sheet of copper of best quality of one millimetre thickness, is about twenty-five metres per second, and is, therefore, in general comparable with the velocities attainable in experiments with rotating apparatus.

When an electro-magnet is suddenly excited on the positive side of the sheet, a system of currents is induced in the sheet, the effect of which on any point on the negative side is, *at the first instant*, such as exactly to neutralise the effect of the magnet itself. The effect of the decay of this system of currents is therefore equivalent to that of an image of the magnet, equal and opposite to the real magnet, from the position of the real magnet, in the direction of the normal drawn away from the sheet, with the constant velocity R.

When any change occurs in an electro-magnetic system, whether by its motion or by the variation of its intensity, we may conceive the change to take place by the superposition of an imaginary system upon the original system; the imaginary system being equivalent to the difference between the original and the final state of the system.

The currents excited in the sheet by this change will gradually decay, and their effect will be equivalent to that of the imaginary system carried away from the sheet with the constant velocity R.

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When a magnet or electro-magnet moves or varies in any continuous manner, a succession of imaginary magnetic systems like those already described is formed, and each, as it is formed, begins to move away from the sheet with the constant velocity R. In this way a train or trail of images, is formed, moves off, parallel to itself, away from the sheet, as the smoke of a steamer ascends in still air from the moving funnel.

When the sheet itself is in motion, the currents, relatively to the sheet, are the same as if the sheet had been at rest, and the magnets had moved with the same relative velocity. The only difference is, that whereas when the sheet is at rest, no difference of electric potential is produced in different parts of the sheet, differences of potential, which may be detected by fixed electrodes are produced in the moving sheet.

The problem of Arago's whirling disc has been investigated by MM. Felici and Jochmann. Neither of these writers, however, has solved the problem so as to take into account the mutual induction of the currents in the disc. This is the principal step made in this paper, and it is expressed in terms of the theory of images, by which Sir W. Thomson solved so many problems in Statical Electricity. In the case of the whirling disc, the tail of images has the form of a helix, moving away from the disc with velocity R, while it revolves about the axis, along with the disc. Besides the dragging action which the disc exerts on the magnetic pole in the tangential direction, parallel to the motion of the disc, the theory also indicates a repulsive action directed away from the disc, and an attraction towards the axis of the disc, provided the pole is not placed very near the edge of the disc, a case not included in the investigation. These phenomena were observed experimentally by Arago, *Ann. de Chimie*, 1826.—ROYAL SOCIETY, *February* 15th, 1872.—*From* MR. GEORGE PREECE.

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## SECONDARY BATTERIES.

By Mr. H. R. KEMPE.

M. PLANTÉ has lately very thoroughly investigated the nature of the actions which take place in so called secondary batteries. The batteries were formed of two sheets of lead, separated from each other by india rubber bands, and then rolled into a spiral together and immersed in glass vases, filled with dilute sulphuric acid and water. In making an experiment with one of these couples, M. Planté observed that when the plates were new, on connecting two Bunsens elements to the plates, oxygen gas appeared almost immediately on the positive plate and oxidised it, covering its surface with a very thin brown film of plumbic peroxide ($PbO_2$). On the negative plate, the hydrogen immediately appeared, after having reduced the thin film of oxide formed by exposure to the air, and on joining the two plates in circuit through a galvanometer, a very energetic but very short current was observed. The short duration of the

current, was due to the film of oxide being very thin, and consequently almost immediately reduced. After keeping the circuit closed until all traces of a current had ceased, it was found that the surface of the plates had not returned to their original condition. During the time that the circuit was closed the peroxide on the plate, which was positive when the charging current was on, had become reduced to the protoxide (Pb O) whilst the other plate had become covered with a coat of the peroxide. On now putting on the charging current, the first portion of hydrogen disengaged, reduced the peroxide on the negative plate, whilst the oxygen developed on the positive plate became absorbed by the protoxide, and the gases did not appear on the surface until these actions were completed, and it is evident that the thicker these coats of oxide are, the longer will be the time before the gases appear. On closing the circuit of the secondary couple, a current was observed as before, but of longer duration, owing to the coats of oxide being thicker. And it was found, that when the coats were very thick, the longer it was necessary to keep on the charging battery before the gases appeared, and also the longer was the duration of the secondary current By sending a number of currents in alternately reverse directions, the coats of oxide were obtained thick enough to require the charging battery to be kept on eight or ten minutes before the appearance of the gases. When the gases do appear, no further action of the charging battery will accumulate any more force. When the couples remained some time out of use, it was found necessary in order to obtain anew the maximum effect, to keep the charging battery on for about an hour, but afterwards the maximum charge was obtained in eight or ten minutes. It is equally necessary to send the charging current always in the same direction, as the reversals which were necessary, when the couple is first set up to prepare the surface, would now have the effect of detaching the coats of oxide As the effects of alternate oxidation and reduction always take place on the same material, the couples will last for a very long time. The secondary couples were found to preserve a charge given them for a considerable time. After charging one for half an hour, it was left for 48 hours, and at the end of that time a sufficient amount of current remained, to raise to a white heat a length of platinum wire. With platinum electrodes the charge, although it remained for a considerable time, was found to be comparatively feeble. The duration of the secondary current was found to depend considerably upon the resistance of the current, through which it discharges itself. Thus, with a high resistance, the current was found to be weak but of long duration, a perfectly constant deflectia was obtained with a galvanometer of a high resistance for half an hour. With a wire of a low resistance the current was much more intense, but lasted but a comparatively short time; a platinum wire, about 8 metres long and 1 millimeter in diameter was kept heated for about a minute. M. Planté has shewn that the amount of charge accumulated in the couples, is exactly equal to the charge given out by the battery: this he did by inserting in the circuit a cell containing a solution of sulphate of copper, and a platinum plate previously weighed: the amount of copper deposited on it evidently would represent the amount of work. The deposit given by the charging battery was found to be precisely the same as that given by the secondary discharge.

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# ON SIGNALS OBSERVED IN A WIRE JOINING THE EARTH-PLATES IN THE NEIGHBOURHOOD OF A THIRD EARTH-PLATE USED FOR A TELEGRAPHIC CIRCUIT.

By G. K. WINTER, Telegraph Engineer, Madras Railway.

IN the course of some experiments on earth-currents, an effect was observed which has led to the discovery of a fact which may be of some practical value, besides throwing additional light upon the part played by the earth in telegraphic circuits.

Although several telegraph lines pass through Arconum, only two are terminated at that station—one connecting it with Cuddapah, a town lying 120 miles to the north-west; and the other, which is very little used, connects it with Conjeveram.

Two earth-plates were imbedded in the ground in a line running east and west, and nearly radial to the office earth-plate; they were about a quarter of a mile apart, and the nearest was about the same distance from the office plate. A wire was erected on separate poles, connecting the two experimental earth-plates. When a reflecting galvanometer, similar to those used for cable signalling, was inserted in this circuit, there was a pretty strong deflection; but riding on this deflection, as it were, were distinct signals, which were ultimately, on comparison, found to agree perfectly with the signals passing on the Cuddapah wire.

The experiments were made in a building at least 150 yards from the telegraph office, and the poles carrying the experimental wire were at least that distance from those carrying the Cuddapah wire. It is utterly impossible, therefore, that any accidental leakage could account for the signals. On other wires running in other directions, and varying from one to two miles in length, the same effects were observed: so that the currents going to earth at the office earth-plate must radiate from it through the earth, and the signals in the experimental wire must have been derived from these radiations.

The signals I have now made perfectly legible by using a thick wire reflecting galvanometer, filling the mirror chamber with water to steady the needle and mirror.

I have, in conclusion, to express my thanks to Mr. Lundy, of the British Indian Extension Telegraph Company, for having kindly lent me a reflecting galvanometer, and one of his staff accustomed to read by the mirror. I may also mention that, when speaking to him on the subject of the signals I had observed, he said he thought they were due to a wire that was terminal at Arconum. I was myself of the same opinion, but had not at that time actually made the comparison.—*Philosophical Magazine.*

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## AMERICAN TELEGRAPHY.

THE Denver and Rio Grande line, Colorado, is conducted under a new method. The engineer alone has charge of running the train. The conductor is an agent and he is also a telegraphic operator. He carries a telegraphic apparatus with him, and stations are attached to telegraph poles—being little more than shelves —and the agent communicates orders to the engineer. The poles are numbered in mile sections, from 1 to 26, and the miles are marked on the poles as if milestones. By this means the engineer, who keeps record of the condition of the track, can report to the master mechanic at the end of the trip, or sooner, any defect within 100 feet by naming the number of the pole and section where work is needed. The master mechanic has charge of maintenance of way, and having reports by telegraph, as above stated, he at once directs where work is to be done.—"THE TELEGRAPHER."

Mr. EDWIN J. LELAND, of Worcester, Massachusetts, brings forward an improved battery which is supposed to operate continuously without requiring attention, so long as it remains provided with the requisite exciting substances. The invention consists in placing within the porous cup containing the platinum element sulphate of mercury, alone or mixed with black oxide of manganese, and in surrounding the cup with water, which is in contact with the zinc. This combination, it is claimed, produces reliable action, and is very economical, as the spent sulphate of mercury falls to the bottom of the cup in a shape to be readily converted.

MEXICAN TELEGRAPH LINES.—From recent official reports to the Mexican Congress, the extent of telegraphic communication in Mexico is as follows:—

| | Kilometers. |
|---|---|
| Mexico to Cuervanaca .. .. .. .. .. .. | 83·80 |
| Mexico to Toluco .. .. .. .. .. .. | 67·04 |
| San Luis to Lacatecas .. .. .. .. .. | 184·36 |
| Lacatecas to Durango .. .. .. .. .. .. | 54·47 |
| Ichuacan to Oaxaca .. .. .. .. .. .. | 272·35 |
| Vera Cruz to Tampico .. .. .. .. .. .. | 288·50 |
| Mexico to Vera Cruz, Ichuacan, Tiavcula and Tulancingo . | 1,045·50 |
| Leon to Guadalajara and Manzanielo .. .. .. | 646·26 |
| Total .. .. | 2,644·28 |

The following list of measurements of the electrical resistance of some of the principal lines in America is of great interest, but unfortunately as the gauges of the wires are not given, it is impossible to draw proper comparisons between any of the wires: however, there is sufficient variety to show that there are several gauges used, and that bad dry joints are apparantly to be met with.

It is a matter of satisfaction to observe that our friends in the United States are alive to the importance of using land lines, offering as little resistance as possible in long circuits. Too much attention cannot be given to this matter, as

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increased resistance is simply another name for decreased speed and the reduction of the resistance in a long, either by improving the wire or increasing its diameter, becomes a necessity.

CHICAGO CIRCUITS.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | 1, | New York | ... | ... | ... | ... | 17·3 | ohms | per mile. |
| | 2, | ,, | ... | ... | ... | ... | 19·1 | ,, | ,, |
| | 3, | ,, | ... | ... | ... | ... | 10·8 | ,, | ,, |
| | 4, | ,, | ... | ... | ... | ... | 20·5 | ,, | ,, |
| | 1, | Buffalo | ... | ... | ... | ... | 18·3 | ,, | ,, |
| | 2, | ,, | ... | ... | ... | ... | 19·3 | ,, | ,, |
| | 1, | Omaha | ... | ... | ... | ... | 21·3 | ,, | ,, |
| | 2, | ,, | ... | ... | ... | ... | 25·3 | ,, | ,, |
| | 1, | St. Louis | ... | ... | ... | ... | 21·7 | ,, | ,, |
| | 1, | Louisville | ... | ... | ... | ... | 19·2 | ,, | ,, |
| | 1, | Cincinatti | ... | ... | ... | ... | 16·1 | ,, | ,, |
| | 2, | ,, | ... | ... | ... | ... | 20·8 | ,, | ,, |
| | 1, | Pittsburgh | ... | ... | ... | ... | 19· | ,, | ,, |
| | 1, | Quincey | ... | ... | ... | ... | 20· | ,, | ,, |

ST. LOUIS CIRCUITS.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | 1, | Pittsburgh | ... | ... | ... | ... | 19·1 | ohms | per mile, |
| | 1, | Kansas City | ... | ... | ... | ... | 16·8 | ,, | ,, |
| | 2, | ,, ,, | ... | ... | ... | ... | 19·4 | ,, | ,, |
| | 1, | Memphis | ... | ... | ... | ... | 20·4 | ,, | ,, |
| | 1, | Cincinnatti | ... | ... | ... | ... | 20·2 | ,, | ,, |
| | 2, | ,, | ... | ... | ... | ... | 19· | ,, | ,, |

CINCINNATI CIRCUITS.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | 1, | Pittsburgh | ... | ... | ... | ... | 19·4 | ohms | per mile. |
| | 2, | ,, | ... | ... | ... | ... | 22·4 | ,, | ,, |
| | 1, | Buffalo | ... | ... | ... | ... | 19·4 | ,, | ,, |

BUFFALO CIRCUITS.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| No. | 1, | Cleveland | ... | ... | ... | ... | 19·6 | ohms | per mile. |
| | 2, | ,, | ... | ... | ... | ... | 35·4 | ,, | ,, |
| | 3, | ,, | ... | ... | ... | ... | 23· | ,, | ,, |
| | 1, | Detroit | ... | ... | ... | ... | 22· | ,, | ,, |

The following account of the new offices of the Western Union Telegraph Company is taken from the *Telegrapher*:—

The new operating room is a spacious apartment, 109 feet in length by 28 in breadth, and about 12 feet in height. The walls are colored with a soft neutral tint, very pleasing to the eye, the window casings being grained in black walnut. The operating tables are uniform in size and design, finished in chestnut and black walnut, and surmounted with elegant nickel-plated gas standards, with porcelain shades. The room is thoroughly well lighted, not only by a range of fourteen windows on the north and east sides, but by a capacious skylight in the ceiling, extending the whole length of the room, which also serves as a most efficient ventilator. Perhaps the original feature of the room, in an artistic point of view, is the switch, which is placed upon the front of a handsomely designed enclosure of black walnut, twelve feet in length by three in depth, placed against the southern wall, midway of the length of the room. Above the switch is hung a frame

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containing finely executed photographic portraits of the General Superintendent, surrounded by all the District Superintendents of the Eastern Division, and flanked on either side by large and excellent likenesses of President Orton and the venerable Professor Morse.

The switch itself, though of exceedingly simple design, is constructed and finished with the utmost elegance. It is of the compact and convenient form known as the "peg" switch, and is divided into three sections, intended respectively for the Eastern, Southern, and Western circuits. Each section contains fifty-four upright straps, and will accommodate an equal number of wires, or 132 wires in all—the whole forming the most extensive switch-board in America, if not in the world. It is twelve feet in length by three in height, and contains no less than 16,000 pieces. A tastefully designed canopy of black walnut surmounts it, while its base is surrounded by a counter of the same material, upon which stand four sets of instruments, so arranged as to be converted at will into two sets of button repeaters. Beneath the lower ends of the vertical straps on the switch-board are placed a corresponding number of spring-jacks, one for each line wire, into which are inserted the edges carrying the instrument wires, loops, &c. The spring-jacks are nickel plated, and the designating numbers of the circuit are engraved upon an ivory plate and attached thereto.

Through a cupola on the roof, all the line wires are brought into the operating room, These are distributed as follows:—

| | |
|---|---|
| From the East ... ... ... ... ... ... ... | 21 |
| ,, ,, West, *via* Albany ... ... ... ... ... | 20 |
| ,, ,, ,, ,, Erie R. R. ... ... ... ... | 8 |
| ,, ,, South ... ... ... ... ... ... | 39 |
| ,, Long Island ... ... ... ... ... ... | 1 |
| ,, N. Y. City and suburbs ... ... ... ... | 30 |
| ,, Branch and "short" wires ... ... .. ... | 12 |
| ,, Auxiliary offices (50 loops) ... ... ... ... | 100 |
| Total ... ... ... .. | 231 |

These wires, each carefully separated from the others, and numbered and ticketed, are brought from the cupola through a double set of lightning arresters to a ledge near the floor, within the enclosure in the rear of the switch, and are thence led through the spring-jacks at the bottom of the switch, where the instrument wedges are inserted, and thence to their respective straps upon the switch, where they connect with the battery wires, which are attached to the horizontal straps of the board.

Gutta percha covered copper wires, made up in cables of eight wires each, carefully enveloped in tarred canvas, lead the main circuits from the instrument wedges at the switch, beneath the floor, to the operating tables, each table of four instruments having its own distinct cable; similarly, a five wire cable, carrying four local battery wires and one return wire, leads from the battery room to each table—the whole forming a most admirable and effective arrangement for accomplishing a result which has usually been found to present many serious difficulties.

The operating tables, twenty-eight in number, are arranged in three rows, running the whole length of the room, and are placed about five feet apart. They are six feet by four in size, and divided by vertical semi-transparent glass screens into four compartments, each accommodating a set of instruments, and affording space for four operators to work conveniently, without any interference with each other. A single Argand burner, with a porcelain shade, furnishes an abundance of light to each table, being placed at the inter-

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section of the cross partitions. A small printed card, affixed to each compartment, gives a list of the offices with which that instrument is in direct connection, for the guidance of the office messengers in the discharge of their duties.

Opposite the switch, on the north side, and midway of the length of the room, is placed the manager's desk, provided with a set of instruments, which can be placed in instant connection with any circuit in the office. Besides him an enclosure of plate glass will contain the testing instruments, consisting of a Siemens Universal Galvanometer and a Varley Differential, with resistance coils. In front of the manager's desk, and in the centre of the room, are arranged the automatic repeaters, of which there are four sets of the Hicks-Milliken variety, and two button repeaters, used respectively for duplicating Eastern and Western press reports on different routes.

Six combination or Phelps' type printing instruments are arranged in a line on the south side of the room, and driven by steam power. Heretofore, these machines have been rotated by manual power, a class of officials facetiously termed "grinders" having been employed for this purpose since the first introduction of printing instruments. The uniform and continuous speed obtained by the use of steam power is found to greatly improve the working of the instruments. Their usual rate of speed is about 180 revolutions per minute, and they turn out an average of 500 messages a day per instrument.

On the south side of the room, between the switch and the printing instruments, is an enclosure surrounded by a counter for the use of the assorting clerks. The messages, taken in at the receiving desks below, are shot through a pneumatic tube, terminating in this enclosure. Other similar tubes bring the messages from the ladies' operating room, the cable room, and the office of the Associated Press. These, as they arrive, are assorted by ten clerks, who deposit them in plate glass receptacles in front of the counter, whence they are at once taken and distributed to the proper instruments by the office messengers. Two copying presses, composed of cylinders continuously revolving by steam power, are connected with this department, and each inward bound message coming from the operators' tables is passed between the rollers, in contact with a sheet of moist copying paper, instantly producing a *fac-simile*, which is filed away, ready for future reference, if necessary. The original message is then provided with a delivery number, and thrown into a drop tube, leading to the delivery department below, or to the city department, as the destination of the message may require.

The main operating room contains:—

98 sets of Morse instruments,
4 ,, Automatic repeaters,
4 ,, Button repeaters,
3 ,, Duplex instruments,
6 Combination printers.

The above being the equivalent of 126 single instruments. The duplex instruments are Stearn's patent, for working in both directions, at the same time, on a single wire, which are being quite extensively used by the Western Union Company. Those now in use connect with Boston, Albany and Buffalo. The latter will soon be arranged to work direct to Chicago, and others added between New York, Philadelphia, Washington, &c., &c.

From this office quite a number of long circuits are worked direct, among which are four Chicago wires, two Cincinnati, one Cleveland, one St. Louis, two Pittsburg, two Buffalo. Eastward there are three cable circuits (two to Plaister Cove, and one to Duxbury), and six Boston, besides one duplex—equivalent to two more. Southward there are, one New Orleans, one Chattanooga, one Charleston, one Augusta, one Richmond, two Philadelphia (printers),

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one Washington (printer), and one duplex, besides three to six Congress wires during a portion of the day.

The resistance of the relays in use in this office varies from 100 to 135 ohms; most of them are about 116 ohms.

The operating room is warmed by hot water pipes, which diffuse a gentle and agreeable heat throughout the apartment. In addition to the lights on the operating tables, the switch and its surroundings will be illuminated at night by a splendid sunlight reflector, placed in the ceiling directly above it.

The ladies' operating room is on the third floor of the building. It is a cheerful and pleasant apartment, and contains eleven operating tables, similar to those in the main operating room. Thirty metropolitan or city wires, and seven railroad and way wires, are worked from this room. It is connected by pneumatic and speaking tubes with the receiving department and main operating room. The city wires do not enter the large switch in the main operating room, but are carried direct to a smaller one on the west wall, which is arranged to accommodate fifty wires, with the necessary battery connections. Seven loops are conducted to the city operating room from the main switch. The cable room is also provided with eight loops, and the commercial news room with fourteen. Five instruments are now worked in the cable room.

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## SAMUEL F. B. MORSE.

THIS very day, eighty-one years ago, was born in the town of Charlestown, Massachussetts, U.S., Samuel Finley Breese Morse, and at that time how little could it have been imagined or surmised that the son of the Rev. Jedediah Morse, D.D., would add more links to the girdle that now almost encircles the world, than any other son of the United States.

To chronicle the demise of any member of our Society is a painful task; we are so young, so newly established, that we can ill spare the loss of any member; how much more so must the task be, how much greater must be our loss, when we have to lament and chronicle the removal of one of our landmarks.

After living to a ripe old age, years longer than the allotted span, Professor Morse passed away on the 2nd of April in his 81st year, leaving a name behind him that must last so long as telegraphy exists.

Morse received an excellent education at Yale College (an institution almost synonymous to one of our universities), where he graduated in 1810. During the time he was at Yale, he was instructed in all that was known at that time of electricity, the acquaintance of the Professor (Silliman) who instructed him, was subsequently renewed, and with the free access that he had to his laboratory, Morse had every opportunity after his college career of keeping himself "au courant" with the progress of electricity.

His natural bent, however, appeared to be the fine arts, and his passion for painting was so great that his father felt it necessary to provide him with better instruction and opportunities than the States could afford. He was accordingly in 1811 sent to Europe that he might receive such instruction, and benefit by the examples of the great masters, so that he might, as far as possible, perfect himself in the art to which he purposed devoting himself.

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In England he had the benefit of introduction to some of the best artists, and during his stay over here he produced some works which classed him at once as a rising and most promising artist. His picture of the "Dying Hercules," exhibited in May, 1813, at the Royal Academy, was much admired, and obtained for him much commendation. He remained for some time in Europe, but returned to America in 1815, and started professionally as an artist; but for some time he led rather a chequered existence, and subsequently he took up his residence in New York, where in 1827 he delivered the first course of lectures on the fine arts ever delivered in America.

From 1829 to 1832 he was in Europe, and it was on his return from France in October, 1832, during the voyage, that he laid the ground work of the Morse Electro-Magnetic Telegraph.

From that time to 1840 he was engaged in perfecting the apparatus, and the universal signal code which bears his name. In the latter year he obtained his first American patent, but it was not until 1843 he obtained a bill from Congress, for making a practical test of the efficacy of the instrument. Sufficient money was voted for the construction of a line from Washington to Baltimore. This line was completed in May, 1844, and the successful working of the apparatus proved most satisfactory to all.

In the earliest form of the apparatus the system of transmission was automatic. The various signs representing the letters, consisting of the well known combination of dots and dashes, were cast into forms, having long or short projections. These were set up in continuous lines, and driven by clock work. Above these angular projections, or teeth, was a lever which dropped between the teeth. At the opposite end of the lever were short wires which dipped into mercury cups, making contact whenever the projecting point of the lever was elevated by the passing teeth. This is about the earliest form of automatic transmission. This plan of transmission was subsequently abandoned for the lever key, which from that time, under one form or another, has invariably been used with the Morse apparatus.

A friend of the late Professor writes of him—"The progress of the telegraph was a part of the career of Professor Morse. Wherever his system is seen—and they are scattered nearly over the whole civilized world—the instruments serve as orators, speaking praise to his name and honor to his nation." "Wherever Professor Morse has visited in either hemisphere, and the isles of the seas, he has been received and respected with the greatest distinction. Many ovations have been given in his honor, and society has appreciated his presence as one of the greatest of the age. His fame has spread throughout the world, and it will stand with increased lustre as long as time lasts."

It would take too much space to give the list of honors received by him, but it is needless to do so. Amongst telegraphists his name is a household word, and so long as the telegraph and time exist, the Morse apparatus and code will always bear testimony of the inventor.

Attempts have been made at times to question his title to the invention, but in America they were satisfactorily settled in his favour; but renewed attempts

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have been again made lately, but here they will not be referred to "D. te mortuis nil nisi bonum."

The grief at his decease has been great in the country which gave him birth, and all honor has been paid to his remains, by not alone the telegraphic world but by the whole of American Society. Here the news of his death, brought by his "Code," by his own language, came as a sudden shock, and the feeling of the British Telegraph Society has been one of sorrow at his death and sympathy with their brethern in America, at the sudden departure from their midst of their Telegraphic father.

The friend quoted before remarks of him, during his life—"He is surrounded with friends, and no one can be found that wishes him an unpleasant pang. His life has been one of temperance, industry, and religion. His benevolence has exceeded his abilities through his whole career. A reward awaits him, richer and purer than all the world can bestow."

He died at his own home at Poughkeepsie, New York. And he is now, it is to be trusted, more able to fathom the mysteries foreshadowed by him in the first message sent over the experimental line in 1844,—

"WHAT HATH GOD WROUGHT."

G. E. PREECE.

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ON ELECTRIC CURRENTS PRODUCED BY THE BENDING OF METALLIC CONDUCTORS.—*Compt. rend.* lxxiv. 44—47.—P. VOLPICELLI.

It was observed by Peltier that when a wire connecting the terminals of a galvanometer is bent, the needle of the galvanometer is deflected, and he concluded that the effects produced could not be accounted for, by ascribing them to currents induced in the moving conductor, by the earth's magnetism.

Volpicelli has repeated and extended Peltier's observations, using for the purpose a delicate mirror galvanometer; but there is nothing in the account of his results to shew that they were due to anything more than terrestrial magneto-electric induction. Such particulars as he gives respecting the strength and direction of the currents obtained are consistent with this view of their origin; for instance, he finds that, when a conductor is bent in a vertical plane, no current is produced when this plane is north and south [*query*: magnetic or geographical?], and that the strongest current is obtained when the plane of bending is east and west; further, when the circuit is confined to a horizontal plane, if the observer stands so that not only the conductor, which is the subject of experiment, but also the galvanometer and the entire conducting circuit are in front of him, a bending which results in an *increase* of the area enclosed by the circuit causes the conductor under examination to be traversed by a current running *from left to right*, while a diminution in the area of the circuit causes a current in the opposite direction.

Communicated by Professor FOSTER.

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ON CHEMICAL EFFECTS RESULTING FROM THE CALORIFIC ACTION OF ELECTRIC DISCHARGES.—*Compt. rend.* lxxiv. 83—87.—E. BECQUEREL.

The author points out that heating effects, similar to those produced by the voltaic arc, can be obtained by aid of the discharge of an induction-coil of ordinary size. In order to get in this way the greatest possible effect, he uses as the positive electrode of the coil a small, slightly concave, circular plate of platinum, having about one centimetre of surface, on which is placed the substance to be operated upon; and, as the negative electrode, a platinum wire, one or two milimetres in diameter, ending in a fine point, which is placed in contact with the substance so as to concentrate the effect of the discharge within a small space. In some cases he augments the effect still further by heating the bottle platinum capsule to redness by a blow-pipe flame, and by mixing with the substance under examination very finely powdered carbon, which yields additional heat by its combustion. The paper contains descriptions of the results thus obtained in several cases.

Professor FOSTER.

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ELECTRIFICATION BY THE FRICTION OF METALS AGAINST GLASS IN PRESENCE OF SULPHIDE OF CARBON.—*Compt. rend.* lxxiv. 179.—CH. SIDOT.

If fifteen to twenty grammes of granulated silver and thirty to forty grammes of pure sulphide of carbon are introduced into a thoroughly dried strong assay-flask of white glass, which is then closed by a good cork, or still better, hermetically sealed before the lamp, electric sparks are produced within the liquid on shaking the flask in a dark room. The glass becomes electrified positively. Similar effects, though less marked, are produced when iron or aluminum is used instead of silver; but copper, zinc, and platinum produced no perceptible result.

Professor FOSTER.

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EXPERIMENTAL RESEARCHES INTO THE DURATION OF THE ELECTRIC SPARK.—*Compt. rend.* lxxiv. 180—184.—F. LUCAS & A. CAZIN.

The authors have shewn in previous communications (*Compt. rend.*, April and June, 1870) that the duration $y$ of the electric spark produced by the discharge of a condenser of surface $s$, between two balls whose distance apart is $e$, may be expressed by the formula—

$$y = h\,(1 - a^{s})\,(1 - b^{i}) \ldots\ldots\ldots\ldots (1)$$

in which $h$, $a$, and $b$ are numerical co-efficients, $a$ and $b$ being less than unity.

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In the experiments from which this formula was deduced, the coatings of the Leyden Battery were connected with the balls of the discharger by copper wires, which were of the same length and thickness in all cases. In a subsequent series of experiments they have investigated the effect of interposing various resistances between the battery and the discharger, and find that, for constant values of $l$ and $s$, the duration can be represented by the formula—

$$y = \frac{y_o}{1 + c\, r^{\frac{4}{5}}} \quad 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where $y_o$ is the duration corresponding to no resistance between the battery and the discharger, $r$ the actual resistance interposed, and $c$ a numerical co-efficient. The two formulæ combined give—

$$y = H \frac{(1 - a')\,(1 - b')}{1 + c\, r^{\frac{4}{5}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

*Cascade discharge.*—If two batteries, whose surfaces measure separately $\alpha$ and $\beta$ are combined into a single battery of surface $\Sigma = \alpha + \beta$, the duration $y$ of its discharge would be given by formula (3); but if the two partial batteries are connected *in cascade*, the duration of the discharge is diminished. Representing the duration in the latter case by $Y$, the authors find that the relations between the times occupied by the two modes of discharge can be expressed by the formula—

$$Y = 4 \left(\frac{\alpha\,\beta}{\Sigma^2}\right)^{\frac{4}{3}} y \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Professor FOSTER.

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## WEST'S INDIA RUBBER CABLE.

IT may be in the recollection of many that a four-wire cable insulated with pure India rubber was laid many years ago to form communication between Hurst Castle and Lymington. It will doubtless surprise a good many that this cable of crude manufacture—actually now twenty years old—is still working.

A specimen was forwarded to me a short time since, and I made a careful examination of it, but as the time is so long since its manufacture, a few details as to its history will not be inappropriate.

Charles West, who was well-known for his fidelity to India rubber as an insulator, had this cable manufactured in the year—in the early part of the year—1852. Its total length was only 2¼ miles, and it consisted of four wires, each wire was of solid copper—No. 16 Gauge—*untinned* and unprepared, insulated with three lappings of *pure* India rubber of a narrow width. These four insulated wires were laid up helically together round a small core of yarn, and were lapped with one stout piece of well-tarred yarn. This serving was laid round in one long length; the sheathing consisted of a number of iron wires *plaited* like window-sash line.

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During the summer and autumn of 1852 this cable remained coiled up in a yard, exposed to every vicissitude of the weather, the alternations of wet and dry, sunshine and shade. It was eventually submerged or buried in the early part of 1853, between Keyhaven, on the Hampshire coast, and Hurst Castle; and a piece was laid also across the Yarmouth river. The latter portion has been removed; the former is still working—at least one wire is—and from that section the piece I examined had been taken. The piece examined had been buried in thick mud near Hurst Castle, covered by the sea from half flood to half ebb. The mud in this portion of the route is always moist, and but little change is effected in it by the ebbing of the water. The piece referred to was cut out in the January of the present year, and was examined and tested a few days afterwards.

The appearance of the cable may be described as follows:—The iron sheathing was oxidised, but still offering a strong protection: on removing the sheathing the yarn was found to be perfect; with a large quantity of tar remaining in it. The strength and general quality of the yarn was remarkable. The insulated wires had been considerably indented by the yarn, and by the lateral pressure of one against the other, they were discoloured externally by the tar, but to all appearances remaining sound, this being evidently so, where they abutted against each other, seemingly in perfect preservation, and of a color unchanged.

The insulation of the short lengths appeared at first good, for on being placed in water, about one division was all that could be obtained on a sensitive Thomson Galvanometer with 100 cells. On working this deflection out, the dielectric resistance came out about 2 millions per mile. However, on testing the different pieces for retention of charge, an electrometer being used, it was found their insulation was inferior, not one of the wires being able to hold its charge for any lengthened period.

This result was not surprising, for with such a manufacture, be it remembered, so long ago, the insulation necessary, and the means of measuring it were very different to what they are at the present time. Although, according to our present acquirements, the insulation of these wires must necessarily be considered as imperfect, yet there remains nothing whatever to show that the insulating material has deteriorated.

Wires insulated in such a manner, strip being served over strip, cannot have been expected to give perfect insulation, it being almost impossible without some curing process (at that time unknown) to make the several coatings homogeneous. It is almost certain that at the time referred to, with the largest amount of battery power obtainable, and the most delicate "detector," the insulation of the wires was found perfect.

On cutting the wires and further examining them, there was found a fair adhesion between the several lappings, and the material of each lapping had preserved not only its color, but also its elasticity. The stripping of the final lapping of rubber shewed the copper wire perfectly *clean*, and with a bloom on it as if it had just been manufactured.

It has been usually considered that bare copper wire next india rubber

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exercises a deleterious effect. The present case would show the contrary, and proves that the necessity of tinning copper wire, where pure rubber *alone* is used is unnecessary.

There are many points in connection with the durability of this india rubber insulated wire, that are of great interest, and offer many opportunities for more lengthened remarks, that perhaps might bring about too long a discussion. I have therefore thought it the most desirable plan to give the history of the cable itself, and the results of my actual observations on it, leaving my readers to form their own conclusions. The remarks I have offered are in the interests of telegraphy, and may, I hope, tend in some way to promote further observations on the durability of insulating material for underground and submarine purpose.

G. E. PREECE.

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## TELEGRAPHIC PROGRESS.

EXTENSIVE preparations are going on for the erection of a number of telegraph lines in Asiatic Russia. This has been brought about in consequence of a treaty concluded between Russia and Persia; amongst these are the extension down the Volga and the Caspian Sea.

The Great Northern, China, and Japan Telegraph are having a cable made at Mr. Henley's, North Woolwich, for placing Amoy intermediate on the Hong Kong and Shanghai section of their cables. The cable is about completed, and will very shortly be despatched to the East.

Mr. Henley is also making a cable for the Montevidean and Brazilian Telegraph Company (a Company recently formed); the length of the cable will be 230 miles. The conductor is insulated with India rubber, manufactured by Mr. Henley, who has recently started this branch of telegraphy at his works at Woolwich. The land line of 400 miles has been contracted for by Messrs. Reid Brothers. The completion of these lines will bring Valparaiso and Santiago in Chili, Buenos Ayres and the other important cities in the Argentine Republic, and Monte Video into electrical communication and closer correspondence also with Europe.

The various Submarine Companies, representing the direct Submarine Cable route to the East, have definitely decided upon amalgamating, as their several interests were almost identical; the Companies affected by this are the Falmouth, Gibralter and Malta, the Marseilles, Algiers and Malta, the Anglo-Mediterranean, and the British Indian, Submarine Telegraph Companies. The arrangement come to as regards division of Capital is to issue to the Stock and Shareholders of the four Companies fully paid-up Shares of £10 each in a new Company, to be formed by a consolidation of the four undertakings, in exchange for their shares and stock in the following proportions, viz:—For each £100 nominal stock in

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the Anglo-Mediterranean Company, £200; Falmouth, Gibraltar, and Malta Company, £120; Marseilles, Algiers, and Malta, £100; and British Indian Submarine Company, £120. These relative proportions are based upon a computation of the present receipts, and an estimate of the prospects of the several concerns. The share capital of the new Company required for the above distribution will be £3,397,000.

The Anglo-Mediterranean Company are extending their operations by purchasing the concessions, and a system of submarine cables now connecting the various important points in the Grecian and Turkish Archipelago; they also propose extensions to Ragusa and Corfu.

The French Atlantic Telegraph Company have contracted for the laying of a fourth Atlantic Cable in the ensuing year. This will be of greater length in one section than their present cable. It is proposed to submerge it from a point near the Land's End, direct to New York. The contractors are the Telegraph Construction and Maintenance Company, who are already engaged on the manufacture of the Cable. The Great Eastern will be employed, and there are many who will be glad to see the Great Telegraph Ship at work again.

There is some probability of another Atlantic Cable being laid in the ensuing year. A Company, the Great Western, having appeared for laying a cable to the Bermuda with branches to St. Thomas and to New York. The contract for this extension has been taken by Hooper's Telegraph Works.

West India and Panama Cable.—On Sunday, March 10th, the steamship "Dacia," of the West India cable fleet, with Mr. Edward Bright on board, entered the port of Aspinwall, the object of the visit being to examine the shore end of the cable laid sixteen months ago, and test its insulation for the entire length laid down. The examination and tests proving satisfactory, the "Dacia" sailed again next day, March 11th, to grapple for the cable near the point at which it was lost. The electric test showed that some three hundred and sixty miles had been paid out. The "Dacia" will merely grapple for the cable till recovered, then buoy it and return to Jamaica to report progress. The steamship "International," which has the new cable on board, will then proceed to complete the work. Our latest advices from Kingston, of the 9th inst., state that the "Dacia," "Suffolk," and "International," were there, but no intelligence has been received of any work being done. Mr. Robert Sabine, C.E., has proceeded to the West Indies for the purpose of making official tests of the various cables laid for the West India and Panama Telegraph Company, connecting the various islands with Cuba and Demerara.

The various cables in the West Indies are now complete, with the exception of the Jamaica and Aspinwall cable. The majority of the Islands are now connected, and telegraph communication is being maintained between Key West in Florida, Cuba, Jamaica, Porto Rico, and the remainder of the principal Islands, with Georgetown and Berbice in Demerara. South and North America are now telegraphically united.

General Smith, President of the International Ocean Telegraph Company, is about to proceed in the "Suffolk" to Havana, to pick up and recover the first

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Havana and Key West cable, which has not been working for some time. On its recovery it is proposed to lay the cable between the same points.

A Convention has been signed between the representatives of the Telegraph Construction and Maintenance Company and the Falmouth, Malta, and Gibraltar Telegraph Company, of the one part, and the Portuguese Government on the other, for the establishment of a cable between Lisbon and the Brazils, touching at Madeira and Cape de Verd.

At their works at Greenwich, the Telegraph Construction Company are making 300 miles of cable for the Atlantic Telegraph Company, to be laid, as a duplicate cable, between Placentia Bay and Sydney. The conductor will be of the usual size, 107 lbs. copper, insulated with 140 lbs. of Willoughby Smith's improved gutta percha.

The French Atlantic cable, between St. Pierre and Duxbury, has lately been broken, but, as the fault was close to St. Pierre, it was easily and speedily repaired. No interruption to communication was experienced, in consequence of the alternative route.

Reuter's cable—Lowestoft to Norderney—was broken on the 21st ult., for the third time since its submergence; it was, however, repaired in the course of a very few days by the Submarine Company, who work and maintain it.

The Australian overland telegraph has been exciting a great deal of interest and discussion, in consequence of its non-completion. The submarine cable from Java to Port Darwin, has been completed since November last, and until the land lines are through, it will, of course, be comparatively useless and unremunerative. The line northward from Port Augusta, has been completed for about 1,200 miles, and southward from Port Darwin, for 300 miles; between these points there is a gap, which has been rendered impassable in consequence of heavy floods from a severe monsoon. Mr. Tod, the South Australian telegraph superintendent, sends the following interesting telegram:—"Roper River, April 5th. Have taken 'Omeo,' steamer (900 tons), 'Yarura,' steamer (500 tons), and 'Bengal,' sailing ship (500 tons), 92 miles up Roper, landing stock and cargo safely. One of the finest rivers in Australia. Wet season extraordinary in severity—stopped all progress—weather now fine. Work will be pushed on rapidly under my personal supervision. Express service will be completed directly; line completed from Adelaide to section E in December; now poled beyond, to near Newcastle Water, and completed from Port Darwin for over 300 miles. I stay on—work till line complete, about July, and return overland to Adelaide; shall be at Port Darwin middle of April, and will telegraph." It is now May, and as yet no further news; the difficulties are apparently greater than Mr. Tod imagined. The Queensland lines are also progressing, and are now about 600 miles from Port Darwin, or about 250 miles only from the Roper River. If this portion of the work, from Port Darwin to Burketown, had been undertaken at first, as originally intended, communication would doubtless have been open long before this time.

G. E. PREECE.

*May 6th*, 1872.

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# EARTH CURRENTS, AND THE AURORA BOREALIS OF 4TH FEBRUARY.

EARTH currents, whether due to the appearance of Auroræ Boreales, or to magnetic storms, are always subjects of interest, although much disliked by the telegraphist on account of the general interruption to business which ensues, but of course are of greater interest when they are found to have spread almost simultaneonsly over the telegraph world.

There have been in past years, doubtless, currents equal in intensity to those which showed themselves on Sunday, the 4th of February, and probably over as great an extent of country; but none have been so generally observed as those on the date mentioned, for the reason that the telegraph wires are extended over far more of the world at the present time than they were a very few years ago. As these extensions increase so the presence of these earth currents will be more generally felt, and by a system of correct observations we may hope to obtain a greater knowledge of their action than has hitherto been possible.

Finding that the Aurora of the 4th February brought with it earth currents of very great intensity, long duration, and universal in its effects, I have endeavoured to bring together such information as I could gather from all parts of the world, so that as far as possible the strength, direction, and duration of these currents might be recorded. In this attempt I have been much assisted by some worthy members of our Society, to whom my thanks are due.

I had hoped to offer some remarks, and attempt to point some conclusions on the whole question; but, unfortunately, several returns have not arrived, and I am compelled to postpone any remarks until our second number; in the meantime I append what information I have been unable to obtain.

I would, however, premise, as explanatory of the paucity of information supplied from some stations, that on the occurrence of such phenomena entirely stopping telegraphic correspondence, the chief of the station has his whole time occupied in endeavouring to restore communication, and consequently he is unable to attempt any experiment, and even at times to make any notes. This is of course made worse on a Sunday when the attendance of staff is limited, and business must be attended to.

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The notes are arranged as near as possible geographically from west to east:—

Duxbury, United States—

"Aurora, 12 to 5 a.m., Greenwich time, Sunday, February 4. Earth "currents tremendously strong. At times unable to keep the spot on "scale with condensers in circuit. Aurora visible all night.

"American lines affected to the East, to the West, to the North, but "not to the South."

Saint Pierre—

"During the whole time of the Aurora, a terrible snow storm. Force "of earth currents just 90 Minotto Cells, upon the two lines, Brest to "St Pierre, and St. Pierre to Duxbury. Towards 10 o'clock observations "made."

Toronto, Canada—

"Extraordinary atmospheric electrical disturbances occurred at Toronto, Canada, on Monday morning last, (5 February).

"It was for a considerable time impossible to work the wires, and the "instruments appeared to be in a blaze of light. The phenomena were "supposed to be in connection with the auroral display generally "observed."—*Telegrapher*, Feb. 10, 1872.

Hearts Content, in reply to enquiry, states as follows—

"This is first I have heard of Aurora on February 4. Entry in "Office Diary—'Earth currents very strong on cable. Valentia's signals "sometimes overpowered.

"Entry in my Diary of 'strong E. currents on cables, a strong "deflection from both cables on a vertical galvanometer."

"Nothing here to show it was Aurora. There was a very heavy gale "from N.E., with snow so that one could not see the sky in any direction, "in fact, the storm was so bad, the men would not leave the office for "their meals, although houses so near."

Valentia Cable Diary, *Aurora*, 4th February, 1872.

"Feb. 3rd. (Saturday) 8 p.m. Kicks and trembling of spot at intervals "on '66 throughout the day.

"Midnight. Very violent kicks and strong discharge on '66.

"Feb. 4th. (Sunday) Midnight to 2.30 a.m. Very heavy kicks and "strong discharge on '65 (probably caused by lightning)."

"Towards the afternoon of Sunday the 4th Earth currents became very "strong on the 1865 cable. They increased so much as to produce sparks "on turning switch, accompanied with a sharp crack like the explosion of "a percussion cap. Specially attracted by this rare phenomenon, Mackey

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"(on duty) sent for me to witness it about 5.20 p m. At that time they "were slightly less than before he sent for me.

"At 5.30 p.m. I took the force of the E current negative from cable "on '65, and it was equal to 59 cells of Minotti's battery, being 1.18 times "as strong as our 50 testing cells.

"By the 'Times' paper I observed that the Aurora was generally "visible all over Europe, Asia and part of Africa the same evening. It "was a brilliant diffused *red* here, similar to the reflection of a large fire "in London on a hazy night.

"This unusual phenomenon so engaged my attention at the time, that I "obtained through the Met. Observatory here, the following particulars "from the Kew Magnetic Registers."

At Kew Observatory, Feb. 4, 1872. Declinometer—

"The first magnetic disturbance at 2.25 p.m.

"The Declinometer decreased $\frac{1}{2}°$ returning at 4 p.m.

"From 4 to 10 p.m. oscillations violent, extending beyond the range "for recording, which is $1\frac{1}{2}°$.

"The rapidity often too great for record, direction being chiefly to "increase Declinometer

"Oscillations gradually diminished to 10 a.m., 5th.

Horizontal Force—

"This rapidly increased after $2\frac{1}{2}$ p.m. having violent oscillations to 5 p.m. "when they compassed the whole range=0·065 English units, and died "away gradually after $10\frac{1}{2}$ p.m.

"Quiet at 7 a.m. 5th.

Vertical Force—

"Movements gradually increased after 3 p.m.

"From 5 to 10 p.m. rapid and across the sheet=0·015 English units, and "scarcely recorded.

"Maximum negative deflection at $9\frac{1}{2}$ p.m.

"From 10 p.m. to 7 a.m. 5th oscillations and force lessened.

"Quiet after $7\frac{1}{2}$ a.m."

Valentia Diary—

"Midnight to 6 am. 5th Feb. (Monday). Discharge very strong from "cable. After 6 a m. no entries of E. Currents."

"The above are all the details I can collect. Had it happened on a "week day instead of a Sunday, I might possibly have watched its effects "more. There is no doubt that the force had been more than it was at "$5\frac{1}{2}$ p.m. when measured by me. The current was equivalent to a "positive (copper) current entering the V. A. end of cable.

J. GRAVES.

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## NOTES OF EARTH CURRENTS ON FEBRUARY 4TH, 1872, HAVERFORDWEST.

*m.*, moderate. *s.*, strong. *v.s.*, very strong.

| Time. | Direction. | Strength. |
|---|---|---|
| a.m. | | |
| 3.30 | — | *m.* |
| 4.0 | — | *m.* |
| | | Gradually disappeared during next half hour — no further sign until |
| p.m. | | |
| 2.10 | + | *m.* |
| 2.20 | + | *s.* |
| 2.30 | O | |
| 2.31 | + | *m.* |
| 2.40 | + | stronger - fluctuating. |
| 3.20 | + | For last five minutes rapidly fluctuating from *v.s.* to zero—now nearly disappeared. |
| 3.45 | + | *v.s.* |
| 3.50 | — | Rapidly reversing direction *v.s.* |
| 3.53 | — | *m.* |
| 4.0 | + | *s.* |
| 4.30 | + | *s.*, fluctuating. |
| 4.50 | — | *s.* |
| 4.55 | — | Needle held firmly down |
| 5.6 | — | Do. do. |
| 5.8 | + — | Rapidly fluctuating to do. |
| 5.15 | — | *m.* |
| 5.16 | + | *s.* |
| 5.23 | — | *s.* |
| 5.27 | + | Reversed rapidly, *v.s.* |
| 5.30 | — | Reversed slower, *s.* |
| 5.40 | + | *m.* |
| 5.47 | — | *m.* |
| p.m. | | |
| 5.50 | + | *s.* |
| 5.55 | O | |
| 6.5 | + | *v.s.* |
| 6.8 | + | *m.* |
| 6.12 | — | *v.s.* |
| 6.23 | + | *v.s.* |
| 6.26 | — | Needle firmly down. |
| 6.38 | — | *s.* |
| 6.40 | — | *v.s.* |
| 7.8 | + | *s.* |
| 7.13 | O | |
| 7.17 | + | *s.* |
| | | From this time up to 10 p.m. currents, though strong and changing direction occasionally, were generally steadier and pos. we were able to work slowly—could not do so before. |
| 10.0 | | Deflections almost clear —continue to change direction, but currents are slight. |
| 10.10 | + | *s.* |
| 10.13 | O | Off |
| 10.23 | — | *s.*, steady. |
| 10.40 | O | |
| 11.0 | — | *m.* |
| 11.35 | O | Off gradually. |
| 11.40 | + | *v.s.* |
| Midngt. | — | Changing direction very rapidly since last entry —now steadier—they continued some time after midnight. |

S. SCAIFE.

Liverpool, 4 February—

"4 p.m. to 6 p.m. Powerful earth currents on every wire, unable to get "Manchester, Leeds, Telegraph St., or in fact any office until 5 o'clock, "Looped wires.

"7.30 p.m. Hughes circuit useless although looped.



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"9.0. Heavy delay on all messages handed in for stations to which we "are stopped by the current.

"11.35. Deflections are now beginning to wear off the south wires— "still show on north circuits."

Manchester—

"4.30 p.m. Deflections appearing on wires very strong.

"5.12 p.m. Deflections still very strong on all wires.

"6.15 p.m. Deflections not so powerful, Leeds asking us to transmit "for Telegraph St., deflections so strong—stopped to Crewe by deflections.

"9.0 p.m. Deflections still too strong.

"12.0 p.m. Transmitting at different parts of the evening in con- "sequence of interuptions by deflections—our communication kept open "by loops."

Manchester Literary and Philosophical Society, February 6.—E. W. Binney, F.R.S., president, in the chair. Dr. Joule, F.R.S., called attention to the very extraordinary magnetic disturbances on the afternoon of the 4th instant, and from which he anticipated the aurora which afterwards took place. The horizontally suspended needle was pretty steady in the forenoon of that day, but about 4 p.m. the north end was deflected strongly to the east of the magnetic meridian, and afterwards still more strongly to the west. The following were the observations made:—

| Time | Deflection from the Magnetic Meridian. ° ′ | Time | Deflection from the Magnetic Meridian. ° ′ |
|---|---|---|---|
| 4.0 P.M. | 0 50 E. | 6.10 P.M. | 1 24 W. |
| 4.30 ,, | 0 47 W. | 6.12 ,, | 1 8 ,, |
| 4.55 ,, | 2 22 ,, | 7.41 ,, | 0 10 ,, |
| 4.58 ,, | 3 0 ,, | 7.43 ,, | 0 0 ,, |
| 5.9 ,, | 3 45 ,, | 8.9 ,, | 0 42 ,, |
| 5.12 ,, | 0 52 ,, | 8.31 ,, | 0 10 ,, |
| 5.23 ,, | 5 36 ,, | 8.54 ,, | 1 18 ,, |
| 5.24 ,, | 2 28 ,, | 8.58 ,, | 0 52 ,, |
| 5.35 ,, | 0 52 ,, | 11.3 ,, | 0 5 ,, |
| 5.55 ,, | 0 52 ,, | | |

Mr. Sidebotham states that he also expected the magnificent aurora, on account of the violent disturbance of the needle at Bowdon, amounting to at least 3°.

Extract from Telegraph Street Diary, Sunday, February 4th—

"5.20 p.m. Since about 4 o'clock all circuits have been very much "affected by deflections. The earth currents have been, and are still so "excessively strong that we can scarcely get even a service message off."

"6.0 p.m. Since five o'clock deflection has increased in strength and "almost unvaried, looping extended to no less than 54 wires.

"Could not work to either Belfast or Dublin, even through the loops "with increased power."

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"7.0 p.m. Deflections continue as intense as before, and with little "variation, extending over every route. Those circuits of looped wires "working with much uncertainty."

"10.0 p.m. Deflections have not disappeared, although not now quite "so strong, many changes in attempting to get circuits through by one way "or another. Working fairly to Dublin separately. Leeds, Manchester, "and Liverpool, report they are in as much difficulty as ourselves, through "the strong earth currents on the north circuits."

"11.0 a.m. Doing better since 10 o'clock."

February 5th—

"2.0 a.m. Earth currents now disappeared."

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*Extracted from* "NATURE," *March 7th*, 1872.

It is unfortunate that more accurate observations of the electrical phenomena accompanying auroral displays cannot be made upon the telegraph wires of this country. The truth is, public business cannot be made to suffer for scientific investigation, and at such moments the disturbance of the wires makes it more than ever imperative that delays should not occur. The whole efforts of the staff are directed to maintain the communications intact, hence the observations made on February 4th are not very numerous, though they are sufficiently interesting to deserve record.

At Portsmouth twenty-six observations were made of the direction and strength of the earth currents on a wire extending from Portsmouth to London, *via* the London and South Western Railway—a length of 74 miles, giving a resistance of 995 ohms. These were as follows:—

| Time. | Direction of. | Strength. | Remarks | Time. | Direction of Current | Strength. | Remarks. |
|---|---|---|---|---|---|---|---|
| 5.54 | P | 30° | The observations were made upon an ordinary vertical galvanometer, and 40 was equal to about 20 Daniell's cells. | 6.41 | P | 40° | No observations made between 6.41 & 7.35. |
| 6. 8 | " | 20 | | — | — | — | |
| 6.11 | " | 10 | | 7.35 | — | 0 | |
| 6.13 | " | 30 | | 7.42 | N | 41 | |
| 6.15 | " | 25 | | 7.56 | " | 68 | |
| 6.17 | " | 40 | | 8.6 | — | 0 | |
| 6.19 | " | 30 | | 8.8 | — | 0 | |
| 6.21 | N | 15 | | 8.15 | N | 35 | |
| 6.23 | " | 24 | | 8.22 | P | 12 | |
| 6.25 | P | 20 | | 8.28 | — | 0 | No observations made between 8.30 & 9.0. P.M. |
| 6.27 | " | 20 | | 8.30 | — | 0 | |
| 6.29 | — | 0 | | — | — | — | |
| 6.31 | P | 8 | | 9.0 | — | 0 | |
| 6.33 | " | 13 | | 9.40 | — | 0 | |

P means Positive from London to Portsmouth.

The officer who made these observations writes:—"Strong deflections arising from earth currents were observed on all circuits except the local ones. The duration of the currents changed from north to south at intervals of a few

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minutes, and varied in strength from 1° to 68°. The strength of the current was proportionate to the length of the wire. Thus Chichester circuit (a short one) was affected less than the Guildford, and the latter less than the London circuits. The working was maintained to London with comparative ease by looping two circuits together at each end." The latter method is that usually adopted to overcome the disturbance due to earth currents, but of course it is only applicable in places where there are two wires or more.

Another officer at the Waterloo Station, London, observed the deflections gradually appear on every needle circuit, of which many concentrate at that station. They commenced about 2 p.m., and from that period to 8 p.m. they had all alike been more or less disturbed. It was noticed that the needles moved over gradually, not by a continuous motion, but by jerks, resembling that of the minute hand of a large clock. This has, however, been proved to be due to the friction of the pivots, and not to any pulsations in the currents.

The currents were always most apparent, and first noticeable on the longest lines, and as the lengths of the circuits terminating at Waterloo are very variable, this gradual appearance was very interesting. Lines running south-west and west appear to have been most affected.

All the wires in the Channel Islands were also very much disturbed. In fact Jersey was broken down to England for three hours, owing to the fact of there only being one cable. The section most affected was that between England and Guernsey. It was also noted that the wires in France were very much influenced.

The records from abroad show that, as in previous cases of storms of this character, the effect has been simultaneous all over the globe. The French Atlantic cable was seriously affected; the strength of the current was at one time equal to 90 Daniell cells. It was at times impossible to read even with condensers in circuit. The American lines were also disturbed in the East, West, and North, but not in the South.

It is much to be regretted that simultaneous observations cannot be made in various parts of the globe, detailing, in comprehensible units of measurement, the direction and strength of these currents, as well as the exact time of their appearance and disappearance. We might then arrive at some knowledge of their cause.

Southampton, Feb. 24th. W. H. Preece.

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M. Tarry, Inspector of Finances, Paris, in a communication to the French Academy, remarks:—

"The disturbance at Rome commenced at 5.30 p.m. local time, and the "greatest effect seen was at 6.31 p.m."

And also that at Brest—

"The maximum deflections were noted at 5.56 p.m. During the whole "duration of the aurora, all the lines terminating at Brest were more or

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"less affected by the magnetic currents, but the longest line, Brest to "Paris, was the most affected. The line from Brest to Rennes, though "on same poles, was much less affected. The direction of the currents "was generally from the east to the west, and lines perpendicular to this "direction suffered least, which besides made themselves felt even on the "shortest lines. At 2.32 p.m. the first currents were perceived; at "3.3 p.m. (Paris time) the work on this line was completely stopped."

During the whole time of the aurora, the cable from Brest to Duxbury was influenced by strong currents, changing suddenly from one sign to the other, the negative current prevailing as in the overground lines. Their intensity, measured at the Brest end, varied from 4 to 65 Daniell cells.

Paris.—M. le Verrier, writing to the French Academy, says:—

"Let me add, in conclusion, that according to a despatch received from "the Director of the Telegraph lines, the earth currents began to be felt "from 3.30 p.m., first upon the eastern lines, Germany and Austria; "towards 4 o'clock the Swiss lines were affected, and the phenomenon "successively came nearer Paris, in passing through Switzerland by "Besançon and Dijon. At 5 o'clock the wires surrounding Paris were "themselves similarly affected."

It may be accepted generally that the earth currents were equally powerful in France, Spain, Germany and Italy. The information obtained from each country is too general to be of great value, the strength of the currents not being measured, and their direction not sufficiently noted.

Gibraltar—

"On 4th February could not work either Morse or Mirror on "Lisbon Cable; all afternoon very strong current on line, Malta also "complained of bad signals through Aurora, we did not suffer so much "from it on Malta circuit. Very strong current on Villa Reale Cable, "much stronger than on Lisbon Cable. Was unable to test either cable "that day through current on lines. At 9.45 p.m. working on Lisbon "and Villa Reale Cables. Nothing visible here of Aurora, electrical "effects visible all day, more or less, but much worse in the after-"noon."—*De Sauty.*

Malta—

"Great electrical disturbances on all our cables from 5.30 p.m. on "the 4th, to 2 a.m. on 5th February, during which time Aurora was "visible. Direction of earth current *positive*, coming from Bona-"*negative* from duplicate Alexandria Cables."—*Portelli.*

Turkey—

Mr. Corunbary, director of the Observatory at Constantinople, writes:—

"Very intense disturbances were observed on all the telegraph lines of "Turkey and Asia Minor. These disturbances took place in the lines, "having a direction spreading easterly—and even upon lines of short length,

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"such as 20 to 25 kilometres. The chief of the meteorological station at "Volona communicated to him.

"After mid-day of the 4th February our telegraphic line was inter- "sected by strong atmospheric currents, gradually increasing in intensity "and frequency until sunset, when they became permanent; the "galvanometer of the telegraph office, although in a circuit of 1,200 "kilometres (Volona to Constantinople) indicated an anomalous deflection "of 65 to 70 degrees, due to a negative current; at 7.35 p.m. the current "changed and became positive, preserving its great intensity."

At the same time similar phenomena were observed at the office at Pera:—

"The chief at Jurgat says that at 6.30 p.m. the apparatus worked "automatically, at 7.0 the current was permanent, at 7.15 communication "became impossible, at 7.30 the galvonometer was demagnetised and "remagnetised instantly, but with reverse magnetism; at 8.15 the "influence was inconsiderable, at 9.0 communication was re-established."

Alexandria—

"Earth currents variable on 4th February. Commenced 7.15, finished "8.45 p.m. Alexandria time. Not very strong. Aurora first observed "6.30 p.m., lasted throughout."—*Stevenson.*

Suez—

"Great electrical disturbances from January 31st to February 5th. "Aurora visible from 6 p.m. of February 4th to 2 a.m 5th. During "which time very strong earth currents on lines."—*Saunders.*

Aden—

"Currents first observed at 6.30 p.m. Did not interfere materially with "working until 8.8 p.m., when we were completely stopped on Bombay "section. Got right to Suez 11.10 p.m., and to Bombay 6.45 a.m. "on 5th."—*Reynell.*

Bombay—

"Strong earth currents 7.30 p.m. on 4th February. Continued till 7.0 a.m. "on 5th. Aurora plainly visible 8.30 p.m. till 4.30 a.m."—*Stacey.*

From the British Indian Submarine Company, by Mr. George Draper, the following intelligence was published in the "Times:"—

"It may interest your readers to know that the brilliant aurora which "was visible in London last night was also visible at Bombay, Suez, and "Malta. Our electrician at Suez reports that the earth currents there "were equal to 170 cells (Daniell's batteries), and that sparks came from "the cable. These electrical disturbances lasted till midnight, and inter- "rupted the working of both sections of the British Indian cable between "Suez and Aden, and Aden and Bombay. Since Thursday last the

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"signals on the British Indian cable have been very much interfered with "by electric and atmospheric disturbances, causing considerable delay in "the transmission of messages, which all efforts failed entirely to over- "come. Our Superintendent at Malta also reports that there was a very "severe storm there yesterday morning, so much so that they were com- "pelled to join the cable to earth for several hours. He also reports the "aurora as very large and brilliant. The electrical disturbances on the "cable in the Mediterranean, and on those between Lisbon and Gibraltar, "and Gibraltar and the Guadiana, were also very great. The signals on "the land line between London and the Land's End were interrupted for "several hours last night by atmospheric currents."

Ispahan, Persia, Feb. 14, 1872—

"We had a splendid exhibition of an aurora on Sunday night (4th) "at 10 p.m. I was called to the office by the clerk to see the earth "currents (as I had ordered) at about 9 p.m., and of course my first look "out was for aurora, but could see none. When I got to the office the "currents were very strong, and somewhat long in duration. They were "at first permanent for a space of 5 minutes together; then they got "shorter, the galvanometer needle going over in a gradual and slow "manner. At other times the deflection would be like as if the signaller "at the other side was sending longish dashes. The course of the currents "was S.E. and N.W. After leaving the office I saw the aurora. The whole "of the Northern sky was crimson up to about 60°, like a magnificent "sunset, with little nebulous clouds floating about, of a deep blood red. "It was seen distinctly at Bushire, and I suppose much lower, but have "not heard." J. R. Preece.

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*Extract from* "Engineering."

Sir,—On the night of the 4th-5th of February, I had the good fortune to witness a grand magneto-electric disturbance on four of the sections of the Persian Gulf telegraphs. It was accompanied by an aurora borealis which must have been one of unusual splendour. Of course I do not suppose that the luminous phenomenon which I beheld was the actual aurora, for as these meteors have their sphere in the region of the clouds they can hardly be more than three or four miles high at the pole, and therefore it is quite impossible that I could have seen anything but a reflection (probably two or three times repeated) at this low latitude, 25½ N.

As seen from Jask station it took the shape, roughly, of an elongated ellipsoid of a reddish pink colour, resting on the northern horizon with its smaller end stretched out towards the east. It continually varied as regards depth of colour, being at one time bright and glowing, and presently appearing

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to fade away. Its position did not alter from its first appearance about* 11 p.m. to 1.30 a.m., when I last saw it. About an hour after sunset a faint whitish glow appeared in the west, and as the evening advanced became more distinct, assuming a pyramidal form with its base on the horizon. There was no moon, and the atmosphere was particularly clear, with a moderate breeze from the north.

The telegraph may be said to stand in the same relation to this class of phenomena as the barometer does to atmospheric changes. A certain behaviour on the part of the former as surely indicates the prevalence of a "magnetic storm," as does that of the latter the approach of an atmospheric one. To me the spontaneous working of the telegraph instruments was (if I may so speak) the harbinger of the aurora, for hours before its reflection was visible the wires told very plainly of its existence.

At 6.55 p.m. a permanent positive current was observed on the Jask Gwadur cable. This was at first set down to some irregularity at the distant station, but such was soon ascertained not to be the case. Presently a similar current, but apparently weaker, was perceived on the land line between the same stations, while at almost the same moment permanent negative currents took possession of the Jask-Bushire and Jask-Fao cables. It was now evident that earth currents were about, and in strong force too, as was seen from the deflections of the galvanometer needles which form part of the working apparatus. I now went out into the open air in the full expectation of seeing some signs in the heavens, and sure enough I was not disappointed, for I quickly detected the white glow in the west, alluded to just now. After a few minutes the direction of the currents changed the cable and land line between Jask and Gwadur became charged with negative electricity, and the Jask-Bushire and Jask-Fao sections with positive. Thus throughout the evening and at intervals of two to five and ten minutes, the currents were ever varying in direction and force. Soon after their appearance it was found very difficult to correspond with any of the distant stations, and from 8 p.m. to midnight communication was entirely suspended, except for a moment at those times when the existing current was dying out to give place to the succeeding one, which rapidly arrived at its maximum strength and in its turn receded.

It was observable that the land line and cable to the eastward of us were always charged with the same kind of electricity, while the Jask-Bushire and Jask-Fao lines were as invariably charged with the opposite kind. I also remarked that the currents were reversed in all the lines at the same time, the one pair changing from positive to negative at the same time that the other pair changed from negative to positive. Those on the Jask-Fao section, which is the longest of the cables (655 knots), at one time reached such a high tension

* The time given in this letter is Kurrachee time, which is about 45 minutes in advance of the true local time.

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that whenever the connection between the line and earth was broken a strong spark was emitted.

Some experiments were made to determine the quantitative strength or intensity of the currents. The highest measured was that on the Jask-Bushire cable, where it was equal to that of 57 Minotti cells. At one time it must have far exceeded this number on the Jask-Fao, for I was unable to obtain from the largest battery power available (80 Minottis), and through the same resistance as the cable as strong a spark as that noted above. The following are a few of the observations taken during the evening:

The first three deflections were observed on a tangent galvanometer, the other three with Sir W. Thomson's delicate mirror instrument.

I cannot vouch for more than the tolerable correctness of what follows in this paragraph; for it is compiled from the diaries of the clerks on duty at the time, and clerks, as a rule, I am sorry to say, take no interest in these matters. Indeed, this lamentable apathy is not confined to the clerks alone. I know it for a fact that it extends to the superior grades. Shortly after midnight the earth currents entirely forsook the land line, or, at all events, became so feeble as to have no appreciable effect on the working. They disappeared from the cable circuits about the same time, but at 12.30 a m. of the 5th they again set in on the Jask-Gwadur cable, and continued at long intervals (during which communication was satisfactory) up to 8 a.m., when they finally vanished, ending with a negative current, which held the line from 7.30 to 7.50 a.m. The Jask-Bushire and Jask-Fao lines were free from midnight to 2 a m., when strong negative currents set in, remaining about one hour. After 3 a m. no further disturbance was reported on the Jask-Fao cable, but the Jask-Bushire was again, and for the last time, visited by negative currents, which continued off and on from 6 to 8 a.m. The regular weekly tests of the cables taken late on the forenoon of the 5th showed that even then the earth currents, although too weak to be observable on the ordinary instruments, had not entirely vanished.

| Time. | Name of Section. | Resistance in circuit. | Earth current deflection. | Name of current. | Calculated strength of earth current. |
|---|---|---|---|---|---|
| P.M. | | units. | degree. | | |
| 8.50 | Jask-F'ao | 5198 | 59 | + | 39 Minotti cells |
| 9.20 | " | 14198 | 33 | + | 41 " " |
| 10.0 | Jask-Bushire | 13508 | 45 | + | 57 " " |
| 11.10 | " | 4330 | 15 | + | 25 " " |
| 11.15 | " | 4330 | 8.5 | + | 14 " " |
| 11.20 | " | 4330 | 8 | — | 13.3 " " |

We are not often inconvenienced with earth currents on these lines. During

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the last four years there were probably not more than six instances, in which the disturbance was serious and lasted for any considerable period. I mysel can only recollect four cases. On one of these occasions (13th-14th May, 1869,) the currents changed on the Jask-Gwadur section from 19 cells (Daniells) positive to 14.5 cells negative in about ten minutes and on the Jask-Bushire line from 21 cells negative to 5 positive within the same time.

One word more—when describing the aurora reflection I said its colour was constantly varying. Now this might be due to clouds passing in front of the aurora or to some changes in the reflecting medium. I will, however, hazard a conjecture that these variations corresponded with the different phases of the aurora itself, and also that they coincided with the alterations of the earth currents.

In conclusion, I have only to add that the Jask-Gwadur cable and land line lie nearly east and west, and the Jask-Bushire and Jask-Fao lines N.W.

J. J. Fahie.

Persian Gulf Telegraph Department, February 20, 1872.

If any of my readers should happen to possess any definite information regarding these earth currents, at places other than I have mentioned, containing particulars as to time, duration, strength and character, I should be very glad indeed to receive them, so as to be able to place on record all the possible information regarding so interesting and general an event. The subject will, I hope, be continued in our next number.

G. E PREECE.

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## ON THE CONSTRUCTION AND SUBMERSION OF SUBMARINE TELEGRAPH CABLES.

By Professor Fleeming Jenkin, C.E., F.R.S., &c.

All submarine cables hitherto laid have consisted of three parts: 1. The conducting wire, generally, if not universally, copper. 2. The insulator surrounding the conductor, generally gutta percha, or some preparation of india-rubber. 3. An outer covering intended to afford protection, and give longitudinal strength. The simplest form of outer covering consists of iron wires laid helically over a jute or hemp serving.

*Conductor*—Copper, being the metal which offers less resistance to the passage of the current than any other commercially available, is employed in all but a few exceptional cases The earliest cables had conductors formed of a solid wire, which has the advantage of occupying less bulk than any strand, and so requiring less insulating material to give the same thickness of coating. This advantage was more than counterbalanced by the brittleness of the solid core, which breaks after being bent a few times, and from this cause frequently caused total interruption of telegraphic communication. A strand of 3 or 7

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wires is therefore now universally used. Messrs Clark and Bright introduced a strand made of wires of such section as to fit into one another, building a truly circular rope, and thus endeavoured to combine the advantage of the strand and solid wire. Many have been unable to carry this plan to any commercial advantage. The strength of copper wire is given in some books as equal to 60,000 lb. per square inch, but the one used in submarine cables is chosen rather for electrical than mechanical properties, and will bear only from 35,000 to 39,000 lb. per square inch. It elongates from 10 to 15 per cent., or even more, before breaking, so that its full strength cannot be made use of; but this extensibility is a very valuable property, since it ensures that the conductor shall not break before the full strength of the protecting cover has been made use of and overcome. A copper strand will bear 1½ lb. per pound weight per knot before breaking. It will stretch 1 per cent. with 1 lb., and will not stretch sensibly with a weight of 0.75 lb. per pound per knot.

Thus a strand weighing 300 lb. per knot, such as was used for the Anglo-American cables, will rarely carry 450 lb., will stretch 1 per cent. with 300 lb., and will not stretch sensibly with 250 lb.

The weight per nautical mile (6087 ft.) of a copper wire of diameter $d$ expressed in thousandths of an inch is $\frac{d^2}{55}$; and if the conductor be a strand, the weight is $\frac{d^2}{70.4}$.

Great care is necessary in making the joint between two portions of the conductor. A scarf joint is first made by soldering together two tapered and fitted ends. Fine copper wire is wrapped round this joint, which is somewhat inflexible, and solder run round the wire. A second wrapping of fine wire is then given, and left without solder. The solder must be applied with resin, and not with spirits of salt.

The joint is necessarily less extensible and more brittle than the rest of the conductor, but if from any cause the soldered joint is broken and stretched so as to open, the fine wire maintains perfect electrical connection, being simply pulled out like a helical spring. The following is a Table of the relative electrical resistances of some metals and alloys at 0° centigrade showing the advantage of employing copper.

(Equal length and diameter.)

| | |
|---|---|
| Silver ... ... ... ... ... | 1 |
| Copper ... ... ... ... ... | 1 |
| Gold ... ... ... ... ... | 1.28 |
| Iron ... ... ... ... ... | 5·94 |
| Tin ... ... ... ... ... ... | 8·09 |
| Lead ... ... ... .. ... | 12·02 |
| Brass ... ... ... ... ... | 4·5 |
| German silver ... ... ... ... | 12·82 |
| Mercury ... ... ... ... ... | 58·15 |

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*Insulator*.—Even the best insulators, such as glass and gutta-percha, do conduct to some extent, but if we were to express these resistances so as to form a construction of the last Table, we should find for gutta-percha

About 60,000,000,000,000,000,000, or 6 by $10^{19}$
And for glass ... ... ... 6 by $10^{26}$

India-rubber has a somewhat higher resistance than gutta-percha, and different preparations differ considerably in their resistances.

India-rubber has been applied in many ways to the conductor. Most commonly tapes of masticated or bottle rubber are wrapped round and round the conductor until the required thickness is obtained. These tubes used to be gummed together by solvents, but this plan was found to cause decay, and has been abandoned. Simple heat has also been applied unsuccessfully, the india-rubber so heated becomes tacky. Mr. Siemens applied the tubes longitudinally, and simply pressed the freshly-cut edges together. This did not make a safe joint. Some manufactures vulcanized the india-rubber, but the material thus formed, although quite homogeneous, absorbed water, was subject to decay, and allowed free sulphur to reach the copper wire. Mr. Hooper's method of applied india-rubber has been the most successful; he covers the conductor with tapes of pure india-rubber next the copper, following by a coating of oxide of zinc and india-rubber, which he calls a separator. The separator is enclosed in a jacket of vulcanised india-rubber. In the process of baking the core to vulcanize the jacket, a little sulphur passes the separator and slightly vulcanises the pure rubber, which is welded into a perfectly homogeneous mass; the core during this process is heated to 250° Fahr. and baked for four hours; it does not become tacky, and is remarkably compact and durable. The joints between two lengths of the insulated core are made with the same materials, and are baked for two hours in a steam jacket. This is the only application of india-rubber which has been thoroughly successful for submarine cables.

Gutta percha is more easily applied, and its use has been attended with almost invariable success; it is pressed out while warm and plastic through a die round the conductor; several successive coatings or tubes are thus applied till the desired thickness is attained. The first coating is attached to the strand by what is termed Chatterton's compound, being a sort of mastic composed of 1 part by weight of Stockholm tar, 1 part of resin, and 3 parts of gutta percha. This compound is also used to fill the interstices in the strand and to attach the successive layers of gutta percha one to the other.

Gutta percha will bear about 3,500 lb. per square inch of section, but owing to its great extensibility it does not add more than about one-third of its strength to the copper strand. It will stretch 50 to 60 per cent. before breaking, and will bear an astonishing amount of ill-usage, such as knotting, squeezing, or stretching, but is easily pierced by a nail or similar sharp tool, or cut by a knife. It becomes soft at the temperature of about 100° Fahr., and after manufacture should never be subjected to a higher temperature than 90° Fahr. The joints

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are made by heating the two ends of the covered conductor after the copper has been joined, and applying by hand successive coatings of warmed and plastic gutta percha, the separate layers of which are also cemented by Chatterton's compound. Much skill and extreme cleanliness are required in making these joints, which were a frequent cause of failure in early cables. If the gutta percha be either over heated or under heated, the junction effected is not permanent, the gutta percha at the joints becomes hard and brittle and shrinks back from the gutta percha of the core, leaving a very visible gap which destroys the insulation. The process is now thoroughly understood, but each joint is made under inspection and subjected to strict electrical tests after completion. When dry and exposed to light, gutta percha very rapidly decays, becoming brittle and porous, but under water it appears to undergo no change whatever. The writer has had great experience and does not know of one instance in which gutta percha has decayed under water. The electric and mechanical properties of the cores of his cables first laid down twenty years ago are as good as ever. The experience with India-rubber is totally opposed to this. All form except Mr. Hooper's rapidly change under water. Mr. Hooper's appears hardly so absolutely permanent as gutta percha, but the change observed does not appear to be material. Hooper's India-rubber will bear much greater exposure to heat than gutta percha, and is much more permanent in dry places. Both gutta percha and Hooper's India-rubber absorb some water, but not to such an extent as to be mischievous. Some forms of India-rubber are rendered unfit for use by this absorption, which in pure India-rubber is such that the material absorbs 25 per cent. of its own weight of fresh water.

The completed core has considerable strength. The Anglo-American cables have a core with 300 lb. of copper and 400 lb. of gutta percha, and this bears without injury ¼ ton quite unassisted by the outer covering; it will stretch ten per cent. under this weight, and may afterwards be knotted and squeezed without any electrical injury being done. Before the application of Chatterton's compound the copper wire used, after a strain had come on the core, to allow the gutta percha to slip back over it without itself returning to its original length. This forced the copper to buckle, and in some cases brought it through the gutta percha. This can no longer occur. The dimensions of the core are determined by the number of words per minute required to be transmitted, and by the total length of the cable With gutta percha cores the ratio of copper to gutta percha in pounds weight per knot varies from equality to two-thirds. The smallest core practically used has 73 lb. of copper and 119 lb. of gutta percha per knot, a more common size is 107 lb. copper and 150 lb. gutta percha. The largest size yet adopted is 400 lb. copper and 400 lb. gutta percha for the French Atlantic.

The number of words which a core will transmit is inversely proportional to the square of the length, and when a constant ratio is maintained between the weights of the insulator and conductor, it is simply proportional to the weight

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of the core per knot. Let $n$ be the number of words per minute which a cable of the length L in nautical miles will transmit with a mirror instrument. Let $w$ be the weight of copper per knot, then,

$$n = C \frac{w}{L^2}$$

where C is a co-efficient varying for the different ratio between the gutta percha and copper. The following Table gives the value of C for several ratios:

| Copper | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
|---|---|---|---|---|---|---|---|---|---|
| Gutta percha | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 |
| Value of C | 163,000 | 175,000 | 187,000 | 196,000 | 205,000 | | | | |
| | | | 21,500 | 22,400 | 23,300 | 24,000 | | | |

If the Morse instrument be used, divide the value of $n$ thus obtained by 14.

If Willoughby Smith's improved gutta percha is used, multiply $n$ in either case by 1.17. This latter value will be correct for Hooper's material also.

Thus a core of 100 lb. copper and 120 gutta percha will transmit 20½ words with the mirror and rather less than 1½ words per minute with a Morse instrument; If Hooper's material or Willoughby Smith's improved core are used, the speeds would be 24 words and 1.7 respectively.

The Morse is restricted to short lengths of cable, thus 250 miles of the above core would transmit by Morse, twenty-seven words per minute, or as much as a clerk can conveniently send by hand the mirror can be read at much more than 30 words per minute; but Sir William Morrison's new recording instrument will receive as fast as the mirror, and leaves a permanent writing which can be read at leisure; with this instrument as much as 120 words per minute may be read if the core will allow it.

*Outer Covering.*—The core is served with hemp or jute applied wet, and either tanned or saturated with brine; originally the hemp had been tarred, but the tar tended to prevent the discovery of faults, sealing up any small aperture temporarily. Sometimes for cables of moderate length several cores 3, 4, or even 7, were laid up together so as to form into strands of hemp, called worming, a circular rope, which was served like the single core into hemp or jute. These multiple cables of course transmitted independent messages through each core. The served core is commonly protected in cables intended for moderate depths by a sheathing of iron wires laid round in a long helix, so as to give the cable the appearance of an ordinary iron rope. The tube which the wires so laid on form cannot diminish in diameter, and hence stretches very little more under a given strain than an iron rod of the same weight per knot would do. The diminution of diameter is prevented by the abutment of each wire against its neighbour, so that the soft heart of the cable undergoes no compression. If the wires are laid on with equal tension, the strength of the completed cable is equal to the sum of the strengths of the wires which compose it. In the spinning or closing machines, as they are called, the wire is wound on bobbins, which as they

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revolve round the axis through which the core passes remain parallel, to themselves, so as not to put a twist in the wire.

A cable so formed is not spongy, and has little liability to kink, that is, to throw itself into a loop when leaving the hold of the ship in which it is coiled. The elongation of an ordinary iron covered cable with half the breaking weight varies from about 0.5 to 1 per cent., an amount which can never injure the core. While being laid the cable generally untwists slightly, but the elongation from this cause also is insignificant.

The iron wire is protected from rust by being galvanised, and still further by being covered with hemp or jute, and a compound of asphalte and silica.

A cable covered with good iron should bear 2 tons per pound of iron wire per fathom.

Thus a cable with 3,750 lb. of iron per knot should bear 7½ tons. This corresponds to an intensity of stress equal to about 41 tons per square inch. The larger gauges and inferior qualities of iron will not bear this. The following Table shows practically the weights borne by wire supplied by Messrs. Johnson, of Manchester.

| B. W. G. | Breaking strains. | Weights per knot. |
|---|---|---|
| | | cwt. |
| 00 | 2067 | 20.59 |
| 0 | 1716 | 16.47 |
| 1 | 1393 | 12.82 |
| 2 | 1212 | 11.49 |
| 3 | 1048 | 9.55 |
| 4 | 873 | 8.06 |
| 5 | 749 | 6.90 |
| 6 | 622 | 5.86 |
| 7 | 530 | 4.61 |
| 8 | 449 | 3.86 |
| 9 | 369 | 3.12 |
| 10 | 306 | 2.55 |
| 11 | 242 | 2.05 |
| 12 | 184 | 1.68 |
| 13 | 144 | 1.28 |
| 14 | 109 | 0.98 |
| 15 | 86 | 0.73 |
| 16 | 66 | 0.59 |
| 17 | 51 | |
| 18 | 39 | |

The smallest number of wires ever used is 9, and this makes too stiff a rope.

Eighteen is a very large number.

Twelve makes a good rope.

A large size of wire is used for shore ends, to protect the cable against anchors, attrition, and rust; for this purpose cables of from 10 to 20 tons per knot are used. The largest size is generally covered with 10 or 12 strands, each

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spun of three galvanised iron wires. A cable so made is much more flexible and easily handled than one covered with solid wires.

Cables covered with ordinary iron are hardly strong enough to resist the strains to which they are exposed while being laid in depths above 1,500 fathoms; above this, homogeneous iron wires (really a variety of steel) are employed. This material will bear from 50 to 60 tons per square inch The Malta and Alexandria cable is an example, which differs in nothing from the shallow water cable except in the substitution of homogeneous iron for ordinary iron.

The main cable between St. Pierre and the United States is a good example of this type.

| | lb. |
|---|---|
| Core copper 7 wire strand weighing per knot .. .. .. | 107 |
| Gutta percha and compound .. .. .. .. .. | 150 |
| Jute yarn serving .. .. .. .. .. .. | |
| Outer covering 10.B B. galvanised .. .. .. .. | |
| Iron wires 0.165 in. diameter weighing per knot .. .. | 4254 |

*Outer Protection.*—For still greater depths recourse is had to a more complex type of cable. Each steel wire is enclosed in a serving of hemp or manilla, the strength of which may be added to that of the steel in calculating the strength of the cable, while the serving adds nothing to the weight of the cable in water. The elasticity of a straight hempen fibre is less than that of most steel, but by choosing the lay of the hemp strands properly, the hemp or steel may be made to stretch so evenly as to give way together, and then the strength of the served wire or cable is found to be actually greater than the sum of the strengths of the compound parts; each part breaks at its weakest point, but these weak points never all occur at the same point in the compound cable, so that we obtain for the strength of the cable the sum of the average strengths of the parts which is, of course, greater than the sum of the weakest parts.

The Atlantic and most other deep sea cables are of this type. The following are the weights of the materials used per knot in the French-Atlantic Cable:—

| | Diam. | inches. | Breaking strain. |
|---|---|---|---|
| Copper 400 lb. per knot | ... | 0.168 | ... 644 |
| G. P. 400 „ | ... | .463 | ... |
| Serving 234 „ | ... | .669 | ... |
| Homogenerous wires (10) | 1,589 | .1 | 950 |
| Manilla strands (50) | 1,091 | | 550 |
| Each served wire | 2,680 | .245 | 1,550 |
| Cable | 3,701 | 1.134 | 1,6530 |
| Weight of cable, in air | ... | 1.652 tons per knot | |
| Weight of cable, in water | ... | 0.753 „ | |
| Strength in tons | | | $7\frac{3}{8}$ tons |

The completed cable is coiled in the works, and on board ship in large circular tanks with eyes from 6 to 8 feet diameter On board the Great Eastern

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the largest tank was 75 ft. diameter, and 16 ft. 6 in. deep, holding 1,100 knots of cable. The diameter of the tank depends on the beam of the ship. One twist per turn is necessarily put into the cable as it is coiled away. This twist as necessarily comes out when the cable runs up out of the tank. In fact, the one operation is exactly the reverse of the other, and leaves the cable as it came from the spinning machine. The cable as it runs up from the tank is led to the centre, and confined to the centre by large wrought-iron horizontal rings, which prevent the line from lashing out under the influence of centrifugal force.

From the tank it runs in troughs to the brake drum, round which it takes four or five turns. This drum is prevented from turning freely by a brake strap, which thus puts the necessary retarding strain on the cable.

It is essential that the restraining friction should be constant, a result obtained by the Appold break. In this arrangement both ends of the break straps are attached to one lever in such a manner that when the break begins to turn it tends to lift the lever and weight hanging from it, and as the lever is lifted it slackens the brake strap, until the difference of tension on the two ends of the strap is equal to the weight hanging on the lever. When this is the case, the lever is no longer lifted, but remains stationary with the strap, allowing the drum to turn, restrained by a constant friction equal to the weight on the lever (reduced to the point where the strap is attached). If the co-efficient of friction increases, the lever will be a little more lifted, and the strap slackened; if the co-efficient of friction diminishes, the lever and weight will fall, tightening the strap; but in any case the retarding force will be simply equal to the weight. After passing the break drum the cable dips under a weighted pulley, which rides suspended on a V of taut cable. If the strain increases, the rope tightens and raises the pulley; if the strain diminishes, the weight and pulley fall. Thus the height of the pulley indicates the strain. This instrument is called the dynamometer. Lastly, the cable passes over the pulley into the sea.

The strains to be provided for may be calculated as follows:

A cable paid out in air hangs in a catenary curve, but a cable paid out in water lies in an inclined shaped line; the strains in the two cases are completely different. In air the rope meets with no sensible obstacle to its motion, either longitudinally or in a direction perpendicular to its own length; in water, on the contrary, each foot of the cable meets with an opposition to its motion perpendicular to its length, which we call $y = Cv_1^2$ where $v_1$ is the velocity of the cable perpendicular to its own length in feet per second. In a rough Atlantic cable, C is about 0·154 times, and as the cable weighs 0·2575 lb. per foot, in cannot sink faster than at the rate of 1.294 ft. per second.

$$\text{for } 1.294 = \sqrt{\frac{0.2575}{0.154}}$$

the result of this resistance to displacement is that the cable lies in a straight

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line (when there is no tension at the bottom), supported as it were by an inclined plane of water continually yielding at the velocity $v_1$, the inclination $\phi$ of the straight line with the horizon depends on the velocity, $v$, of the ship, and on $v^1$

Let $w$=the weight of the cable per foot in water and $m=yv^2$, then,

$$\cos \phi = \sqrt{\frac{w^2 + 4m^2 - w}{2m}}$$

from this formula, as from common sense, it appears that the greater the value of $y$ and $v$ the smaller the inclination with the horizon. The rough Atlantic cable, when the ship was going at the speed of six knots per hour, was at an angle of $6\frac{3}{4}°$, so that the inclined plane was 17 miles long, and each foot of the cable took nearly 3 hours to reach the bottom.

The strain T at the top of the inclined plane, if there were no friction tending to prevent the rope from slipping back, would be equal to the weight of a piece of cable having plumb from the surface to the bottom or

$$T=wx,$$

$x$ being the depth in feet.

There is, however, a sensible friction which helps to relieve the strain precisely as when a rope is lying on a solid inclined plane. Calling $m^1$ the resistance due to friction on each foot of the cable when running out at the velocity, $v_{111}$, we have $m_1=y_1 v_{111}^2$, and experiment shows $y_1$ to be not very different from ·00,504, and from these figures we find that when slack is paid out at the rate of 1 knot per hour, the strain is relieved by about 0·81 cwt. per knot.

The strain, $T_1$, when the ship is running at the velocity, $v$, and the cable enters the sea at the greater velocity, $v_{111}$, is given the following formula:

$$T_1 = wx - m_1 \frac{\left(\frac{v_{111}}{v} - \cos \phi\right)^2}{\sin \phi} x$$

Cables of light specific gravity have a small settling velocity, and lie at great length in the water; and if they are also rough, the co-efficient $y$ may easily be so great as to relieve the break from most of the strain which would be necessary to lay a cable of equal weight, but small bulk, and smoother surface with the same amount of slack. If no slack were laid there would be little difference between the tension required for cables of different construction, but of different weights in water When much slack is laid, all cables will be considerably less strained than if laid without slack; and, finally, the faster the ship goes, the less slack is required to produce any given amount of relief.

The correctness of the above theory has been amply proved in practice. If in seas 2 miles deep, the cable hung in a catenary $12\frac{3}{4}$ miles long, the weight to be carried would be $8\frac{1}{2}$ tons, and the strain on the cable 29 tons; while if the

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cable hung in a catenary, the inclination of which to the horizon at the stern was 9 deg. 30 minutes, the length would be 24 miles, the weight 17 tons, and the strain 102 tons instead of about 14 cwt., the strain actually observed for the Atlantic cable when being paid out at the rate of 7 knots per hour, while the ship was going at 6 knots. The rise and fall of the ship even in heavy weather alter the strain very little.

Communicated by G. E. PREECE.

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## ON MEASURING TEMPERATURES BY ELECTRICITY.

By C. WILLIAM SIEMENS, D.C.L., F.R.S., M.R.I.

[Read before the Royal Institution of Great Britain.]

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THE truth revealed to us by one of the younger branches of physical science, which has been cultivated and expounded nowhere more effectually than within these walls, has divested heat and electricity of their mysterious character, and has taught us to regard them simply as "modes of motion."

Light also has been shown to be identical in its nature with heat, and the only remaining physical agency, "chemical affinity," has been recognized as a force differing only in "quality of action" from the others. According to these views, force, in whichever type of action it presents itself, is as *indestructible as matter itself*, and is therefore capable of being *stored* up and *measured* with the same certainty of result. We have a unit of force or the foot lb., and a unit of heat, or the heat necessary to raise the temperature of 1 lb. of water through one degree Fahr., and it has been already proved that 772 units or force are the equivalent value of one unit of heat. Again, the chemical force residing in 1 lb. of pure coal is equal to about 14,000 heat units, or $14{,}000 \times 772 = 10{,}808{,}000$ ft. lbs. = 4825 tons lifted one foot high.

Questions regarding the quantitative effects of heat present themselves, however, much less frequently for our consideration than questions regarding its *intensity*, upon which depends the nature of the phenomena surrounding us at every step, both in science and in ordinary life. The instrument at our command for determining moderate intensities or temperatures, the mercury thermometer, leaves little to be desired for ordinary use; but when we ascend in the scale of intensity, we soon approach a point when mercury boils, and from that point upward we are left without a reliable guide. The result is, that we find in scientific books on chemical processes, statements to the effect that such

or such reaction takes place at a *dull red* heat, such another at a *bright red*, a *cherry red*, a *blood red*, or a *white* heat—expressions which remind one rather of the days of alchemy than of chemical science of the present day.

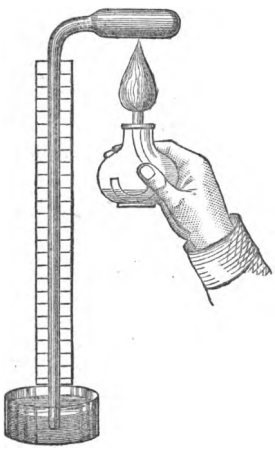
There are pyrometers, it is true, but these are either of a complex nature, or little reliance can be placed on them.

It is my purpose this evening to place before you an instrument by which I hope to fill up to some extent the existing gap. It is the result of occasional experimental research, spread over several years, and it aims at the accomplishment of a double purpose, that of measuring high temperatures, and of measuring with accuracy the temperatures of *inaccessible* or *distant* places.

But before entering upon the details of my subject, I propose to place before you an instrument which fulfils, in principle, all the conditions essentially necessary in thermometry, and is at the same time the very first instrument that was ever proposed for measuring temperatures. I speak of the *air thermometer* by Galileo! It can be shown on theoretical grounds, that the expansion of a permanent gas at constant pressure is the most perfect index of temperature. It is, in fact, the degree of energy of the atomical motion in an elastic fluid which determines its volume, and which constitutes at the same time its temperature.

The air thermometer consists simply of a bulb of glass with a long tubular stem, open to the atmosphere at its extremity. If I heat the bulb (by dipping it for instance into boiling water) and put it into a holder, with the hollow stem reaching downward into a cup of mercury, the air within the bulb will no longer communicate directly with the atmosphere, because the mercury is interposed. If now I cool the air within the bulb, by the external application of iced water, its heat motion will diminish, and its volume would be reduced proportionally, if the external atmosphere could enter freely to fill up the vacancy thus created. But inasmuch as the external air cannot enter, a reduction of pressure will take place, which, according to the law of elasticity by Boyle, must be proportionate to the reduction of volume at constant pressure. The difference of pressure thus created between the bulb and the external atmosphere will be balanced by the column of mercury rising up into the tube, and the elevation to which the mercury attains is a true index of the temperature to which the air in the bulb had been previously heated. This is true with regard to all temperatures, from the lowest to the highest, and the instrument may be termed a universal thermometer. If the bulb could be cooled down to

FIG. 1.



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273° Centigrade below the zero point, it would follow by the law of Charles that the elastic pressure of air would be reduced to nothing, that is to say, the motion of the particles of air, which we call heat, would have ceased, and we should have reached the point of absolute zero, a point which has been theoretically established also by other means.

Practically, such an instrument would be most inconvenient; its indications would have to be corrected by calculation for barometrical variations; the capacity of the descending tube, which contains air not subjected to variation of temperature, would have to be taken into account, and no reliable observations could be arrived at, without taking special precautions, such as are only within reach of the experimental physicist.

[The other known methods of measuring ordinary and furnace temperatures were here passed in review, and the limits of their application pointed out. They were classified into:

Thermonecters, by expansion of liquids.

Thermonecters, by the expansion of solids.

Pyrometers, by chemical decompositions of solids, comprising Wedgwood's and Deville's pyrometers.

Pyrometers, by observing the melting-point of metals.

Pyrometers, by thermo-electricity.

Pyrometers, by exposing a copper or platinum ball of known heat capacity to the heat to be ascertained, and of quenching it in a measured quantity of water.]

The instrument which forms the subject matter of my discourse presents many points of analogy with the air thermometer, if we substitute "*electrical resistance in conductors*" for "*expansion of gases*"! Both these effects are functions of temperature, increasing with the temperature according to progressive laws, which in the case of the gases we call the *law* of *Charles*, and in the case of conductors, the law of "*increase of electrical resistance with temperature.*" The latter law, which is of recent origin, had already been partially developed by Arndsen, Swanberg, Lenz and Werner Siemens, when my attention was directed, in 1860, towards an application of the same to the measurement of temperatures at places inaccessible to the ordinary thermometer. By means of the contrivance which I shall describe presently, I was enabled to tell, in the testing cabin of a cable ship, the increasing temperature of the interior of the mass cable in the hold, and to prove the necessity of transhipment of the same into a vessel fitted with water-tight tanks, which have been resorted to ever since, to avoid the danger of softening the gutta-percha covering.

I have arranged an apparatus for proving to you in the first instance that the conductivity of a wire of platinum or other metal is greatly influenced by its temperature; for this purpose I direct the current of a galvanic battery at will through two branches of equal resistance, each branch comprising a free spiral wire of platinum and one of the coils of a differential galvanometer. By

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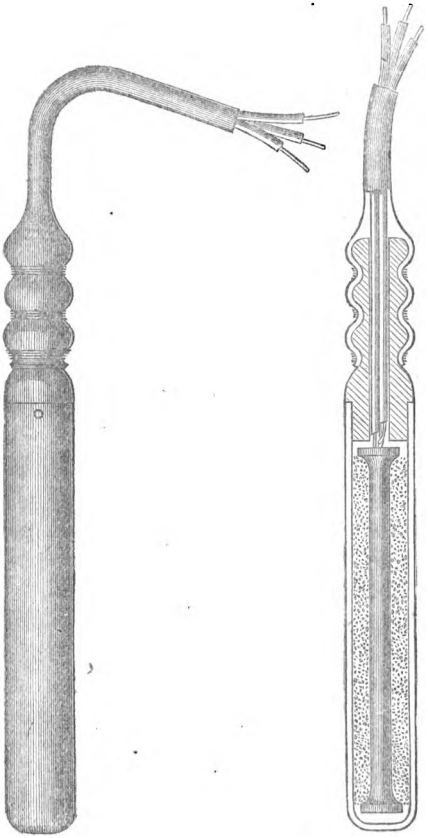
throwing the powerful light of an electric lamp upon the face of the differential galvanometer, and by throwing the image by means of a mirror and lens upon the screen, the audience will see any movement of the needle to the right or the left that may take place when I complete the battery connection. The resistance of both branch circuits being the same, no deflection of the needle is observable on depressing the key, but when I pass the flame of a spirit-lamp under the one platinum coil, the needle is thrown immediately over to the right, because the electrical resistance of the heated wire is increased, and consequently a larger proportion of the current is passing through the cooler circuit, exercising a preponderating influence upon the galvanic needle. When I withdraw the spirit flame from the wire the needle rapidly returns to its zero position, but in passing it under the other spiral wire the needle immediately deflects in the opposite direction.

Fig. 2.



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If instead of using the open spirals I were to wind thin insulated wire of any pure metal upon two small cylindrical pieces of wood, and were to enclose the tiny spirals in small silver casings, as shewn in view and in section by Fig. 2, taking care that the extremities of the spiral wires were soldered to thicker insulated wires leading respectively to the battery and differential galvanometer before mentioned, it follows that no deflection of the needle ensues when both the protected and equal spirals are dropped into a jar containing iced water. But if I take one of the spirals from the water, and place it, for instance, by his kind permission, into the hand of our President without disconnecting the same from its leading wires, the balance of resistance will no longer take place, and a deflection of the needle to the right actually

takes place. I will now endeavour, however, to re-establish the equilibrium by adding warm water to the iced water surrounding the comparison coil near me until no deflection of the needle is observable. This result being obtained, it follows that the temperature of the water surrounding the one coil must be identical with the temperature of our President's hand, and the delicate mercury thermometer which I have placed in my solution must give me the temperature of the distant place which I intended to measure. The temperature here observed is 89 5° Fahrenheit, which is at this moment that of Sir Henry Holland's hands. This result is independent of the ratio in which the electrical resistance increases with temperature in the similar coils, and considering that the silver casings containing the coils are not larger than small pencil-cases, this method might be advantageously employed in physiological research. The one coil would only have to be placed within the cavity to be measured to enable the observer to read the temperature from time to time, without disturbing the patient, with the accuracy of which the mercury or spirit of wine thermometer employed is capable. But the same method is applicable for measuring the temperatures of distant or inaccessible places, such as the interior of stores or cargoes of materials liable to spontaneous combustion; of points elevated above the surface of the ground; or of great depths below for meteorological purposes; or for measuring the temperature of the sea continuously in attaching such a coil to the mariner's sounding lead. An error would in such cases arise, however, through the uncertainty of the resistance of long leading wires, if a complete remedy of error from such a source had not suggested itself. This consists in uniting three separate insulated leading wires, into a cable by which the distant coil is connected with the measuring instrument. One galvanic circuit passes from the battery through one of the leading wires, through the distant spiral and back again through the second leading wire to the differential galvanometer and the battery, and the second passes from the same battery through the near coil, and through the third leading wire up to the distant coil without traversing the same, and back again through the second leading wire to the galvanometer and battery. Thus both galvanic circuits comprise the leading wires up to the distant coil, and all variations of resistance by temperature to which the leading wires may be subjected, affect both sides of the balance equally. In constructing coils for measuring deep-sea temperatures a large quantity of insulated copper or iron wire is wound upon a metallic tube open at both ends to admit the sea-water freely in order to impart its temperature to the innermost layers of the insulated wire. The coil of wire is protected externally by drawing a tube of vulcanized india-rubber over it, which in its turn is bound round by a close spiral layer of copper wire, whereby the sea-water is effectually excluded from the sensitive coil. By these arrangements the temperature of distant or otherwise inaccessible places can be accurately ascertained; but the method is limited to the range of temperature which can be obtained and measured in the comparison bath. In

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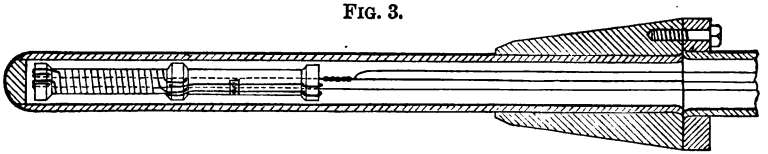
order to realize a pyrometer by electrical resistance, it is necessary to rely upon the absolute measurement of the electrical resistance of a coil of wire which must be made to resist intense heats without deteriorating through fusion or oxidation. Platinum is the only suitable metal for such an application, but even platinum wire deteriorates if exposed to the direct action of the flame of a furnace, and requires an external protection. The platinum wire used has, moreover, to be insulated and supported by a material which is not fused or rendered conductive at intense heats, and the disturbing influence of leading wires had in this case also to be neutralised. These various conditions are very fully realised by the arrangement represented on the following diagram, Fig. 3.

FIG. 3.



Thin platinum wire is coiled upon a cylinder of hard-baked porcelain, upon the surface of which a double-threaded helical groove is formed for its reception, so as to prevent contact between the coils of wire. The porcelain cylinder is pierced twice longitudinally for the passage of two thick platinum leading wires, which are connected to the thin spiral wire at the end. In the upper portion of the porcelain cylinder the two spiral wires are formed into a longitudinal loop, and are connected crossways by means of a platinum binding screw, which admits of being moved up or down for the purpose of adjustment of the electrical resistance at the zero of Centigrade scale. The porcelain cylinder is provided with projecting rims, which separate the spiral wire from the surrounding protecting tube of platinum, which is joined to a longer tube of wrought iron, serving the purpose of a handle for moving the instrument. If the temperatures to be measured do not exceed a moderate white heat, or say 1300° Centigrade =2372° Fahr., it suffices to make the lower protecting tube also of wrought iron, to save expense. This lower portion only, up to the conical enlargement or boss of iron, is exposed to the heat to be measured. Three leading wires of insulated copper united into a light cable connect the pyrometer with the measuring instrument, which may be at a distance of some hundred yards from the same. They are connected by means of binding screws at the end of the tube to three thick platinum wires passing down the tube to the spiral of thin platinum wire. Here two of the leading wires are united, whereas the third traverses the spiral, and joins itself likewise to one of the two former, which forms the return wire for two electrical circuits, the one comprising the spiral of thin wire, and the other returning immediately in front of the same, but traversing in its stead a comparison coil of constant resistance. The measuring instrument may consist of a differential galvanometer as before, if to the constant resistance a variable resistance is added. If the pyrometer coil were to be

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put into a vessel containing snow and water, the balance of resistance between the two battery circuits would be obtained without adding variable resistance to the coil of constant resistance, and the needle of the differential galvanometer would remain at zero when the current is established. But on exposing the pyrometer to an elevated temperature the resistance of its platinum coil would be increased, and resistance to the same amount would have to be added to the constant resistance of the measuring instrument, in order to re-establish the electrical balance. This additional resistance would be the measure of the increase of temperature, if only the ratio in which platinum wire increases in electrical resistance with temperature is once for all established. This is a question which I shall revert to after having completed the description of the pyrometric instrument.

Although I have explained that by means of a differential galvanometer and a variable resistance (constituting in effect a Wheatsone bridge arrangement) the increasing resistance of the platinum spiral may be measured, it was found that the use of a delicate galvanometer is attended with considerable practical difficulty in iron-works and other rough places where it is important to measure elevated temperatures, or on board ship for measuring deep-sea temperatures. I was therefore induced to seek the same result by the conception of an instrument which is independent in its action from tremulous motion or from magnetic disturbance caused by moving masses of iron, and which requires no careful adjustment or special skill on the part of the operator. This instrument is represented by Fig. 4, and may be termed a chemical resistance measurer or "differential voltameter." The immortal Faraday has proved that the decomposition of water in a voltameter expressed by the volumes of gases V. is proportionate in the unit of time to the intensity I of the decomposing current, or that

$$I = \frac{V}{T}.$$

According to Ohm's general law, the intensity I is governed by the electromotive force E, and inversely by the resistance R, or it is

$$I = \frac{E}{R}.$$

It is therefore

$$\frac{V}{T} = \frac{E}{R} \text{ or } V = \frac{E\,T}{R};$$

or the volume V would give a correct measure of the electrical resistance R if only the electro-motive force E and time T were known and constant quantities. But the electro-motive force of a battery is very variable; it is influenced by polarization of the electrodes, by temperature, and the strength and purity of the acid employed. The volumes of gases obtained is influenced, moreover by the atmospheric pressure, and it is extremely difficult to make time observations

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correctly. It occurred to me, however, that these uncertain elements might be entirely eliminated in combining two similar voltameters in such a manner that the current of the same battery was divided between the two, the one branch comprising the unknown resistance to be measured, and the other a known and constant resistance. The volume of gas $V^1$ produced in this second voltameter, having a resistance $R^1$ in circuit, would be expressed by

$$V^1 = \frac{E\,T}{R^1},$$

and we should have the proportion of

$$V : V^1 = \frac{E\,T}{R} : \frac{E\,T}{R^1};$$

or E and T, being the same in both cases, may be struck out, and the expression will assume the simple form

$$V : V^1 = R^1 \div R.$$

The constant resistance R of the one circuit being known, it follows that the unknown resistance $R^I$ is expressed by $\frac{R^V}{V^1}$; that is to say, by a constant multiplied by the proportion of gas produced in the two voltameters irrespective of time, or strength of battery, or temperature, or the state of the barometer.

The resistance R and $R^I$ are composed each of two resistances, namely, that of the principal coils, which we may term R or $R^I$, and of the voltameter and leading wires, which is the same in both cases, and may be expressed by $y$. The expression should therefore be written as follows:

$$V : V^I = R^I + y^I : R + y,$$

$R^I$ being the unknown quantity.

The mechanical arrangement of the instrument will be understood from the diagram, Fig. 4; and the whole arrangement of the pyrometer, with its leading wire and resistance measurer, from the general view given in Fig. 5. The voltametric resistance measurer consists of two calibrated vertical tubes of glass of about 3 millimètres diameter which are fixed upon a scale showing arbitrary but equal divisions. The upper ends of the tubes are closed by small cushions of india-rubber pressed down upon the openings by means of weighted levers, whereas the lower portions of the tubes are widened out and closed by plugs of wood, through which the electrodes in the form of pointed platinum wires penetrate to the depth of about 25 millimètres into the widened portions of the tubes. By a side branch the widened portion of each vertical tube communicates by means of an india-rubber connecting pipe to a little glass reservoir containing acidulated water, and supported in a vertical slide. In raising the weighted cushions closing the upper ends of the vertical tubes, and in

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adjusting the position of the small reservoirs, the acidulated water will rise in both tubes to the zero line of the scale. In turning a button in front of the tubes the battery current is passed through both pairs of electrodes, the one circuit comprising the permanent resistance R and the leading wires up to the pyrometer, and the other the leading wires and the pyrometer coil. If the resistance of the pyrometer coil should be equal to the permanent resistance R, the $R^1+y$ will be equal to $R+y$, and therefore $V=V^1$, but as the resistances will differ, so will the volumes. Necessary conditions are: that both reservoirs are filled with the same standard solution of pure water with about 10 per cent. of sulphuric acid, that all

FIG. 4.

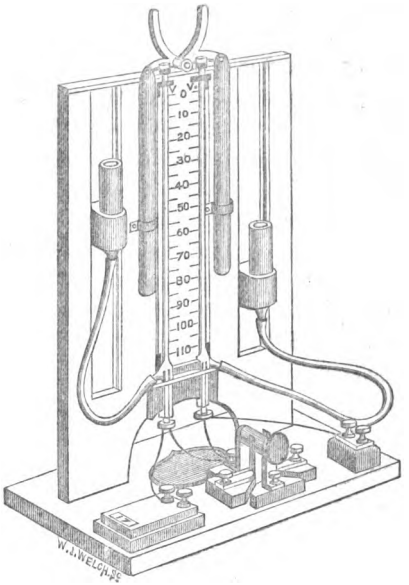
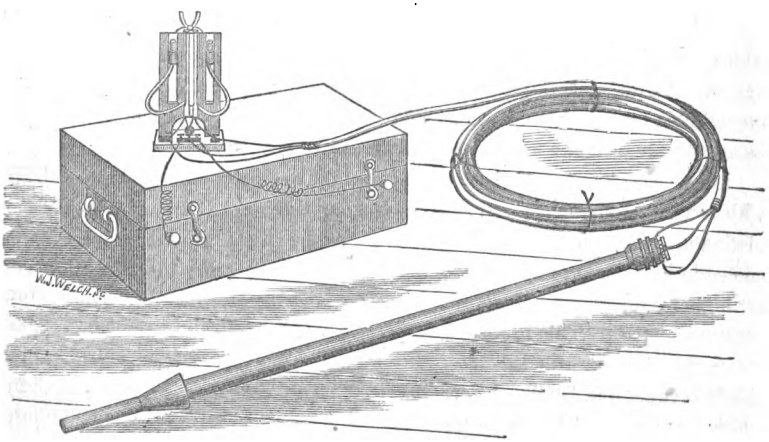



FIG. 5.




the electrodes are of the same form and size, and that their polarity is reversed frequently during the progress of each observation, in order to avoid unequal polarization. With these precautions, which involve no particular skill or knowledge of electrical observation on the part of the operator, very accurate results are obtained; but in order not to incur considerable error of observation

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it is advisable to continue the current, reversing the same say twice, until at least forty divisions of gases are produced in the least activated tube, which operation will occupy from two to three minutes, if a battery of from four to six Daniell elements is employed. The volumes V and $V^1$ being noted, after having allowed half a minute for the gases to collect after the current has ceased, the weighted cushions upon the tubes are raised in order to allow the gases to escape, when the water levels will immediately return to their zero position, to make ready for another observation. By inserting the observed values for V and $V^1$ into the expression above given, the unknown resistance $R^1$ can be easily calculated; but in order to facilitate the use of the instrument I have prepared a Table which gives at a glance the resistance due to any two observed volumes, the volumes V governing the vertical, $V^1$ the horizontal columns, and the resistance being read off at the point of intersection. At each point of intersection the resistance is marked in black, and the corresponding temperature in red ink.

It now remains only to be shown what is the relation between the resistance and temperature in heating a platinum wire. The researches of Dr. Matthiesen, who has made the latest investigations on the effect of temperature upon electrical resistance, are restricted to the narrow range of temperatures between 0° and 100° Centigrade, nor do they comprise platinum. He adopted the following general expression for the pure metals:

$$R_t = \frac{R_o}{1 + x\,t + y\,t^2},$$

which, in determining the specific values of $x$ and $y$ for each metal, gives a close agreement with observation between the narrow limits indicated, but is wholly inapplicable for temperatures exceeding 200° Centigrade, when the value $t^2$ commences to predominate and to produce absurd values for R.

It was necessary for my purpose to undertake a series of elaborate experiments with a view of finding a ratio of general application. Coils of thin wire, of platinum, iron, copper, and some other metals, were gradually heated and cooled in metallic chambers containing the bulbs of mercury thermometers, and for higher temperatures of air thermometers, and the electrical resistances were carefully noted. The progressive increase of electrical resistance was thus compared directly with the increasing volume of a permanent gas (carefully dried) between the limits of zero and 470° Centigrade and a ratio established, which is represented by the formula.

$$R_t = \alpha\,T^{\frac{1}{2}} \times \beta\,T \times \gamma,$$

in which T signifies total temperature counting from the absolute zero, and $\alpha\beta$ and $\gamma$ specific coefficients for each metal. According to this formula the

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electrical resistance is a constant at the absolute zero, and progresses in a ratio represented graphically by a tipped-up parabola, approaching more and more toward a uniform ratio at elevated temperatures. Although the comparison with the air thermometer could only be carried up to 470° Centigrade, the general correctness of the ratio of increase just stated has been verified by indirect means in measuring progressive heats, and by comparison with the platinum ball pyrometer.

It is important to mention here that great care must be exercised in the selection of the platinum wire for the measuring spiral, platinum wire having been met with conducting only 4·7 times better than mercury at zero, Centigrade, and others; conducting 8.2 times better than mercury, although both samples had been supplied by the same eminent makers, Messrs. Johnson and Mathey. The abnormal electrical resistance of some platinum wire is due chiefly to the admixture of iridium or other metals of the same group, and it appears that the platinum prepared by the old welding process is purer and therefore better suited for electrical purposes than the metal consolidated by fusion in a Deville furnace.

In conclusion, I shall show some working results of the pyrometer in measuring by means of the same protected coil a mixture of ice and water, boiling water, molten lead, and the fire itself by which the lead is melted, the readings produced being 2° Centigrade, 98° Centigrade, 330° Centigrade, and 860° Centigrade respectively. The latter temperature signified a cherry red heat, as may be judged by the appearance of the tube when withdrawn from the fire. The instrument which I have had the honour to bring before you this evening has already received several useful applications. Through its first application an important telegraph cable was saved from destruction through spontaneous generation of heat. Professor Bolzani, of Kasan, has made some interesting applications of it for recording the temperature at elevated points, and at points below the earth's surface. Mr. Lowthian Bell has used it in his well-known researches on blast furnace economy; and at several iron-works pyrometer tubes are introduced into the heating stoves, and permanently connected with the office, where the heat of each stove can at all times be read off and recorded. These and other applications are sufficiently self-evident, if the soundness of the principles upon which I rely is conceded; but I feel that the shortness of time at my command has hardly enabled me to do more than to pass these in review, while endeavouring to demonstrate the results obtained of recording the temperatures of distant or inaccessible places, including furnace temperatures.

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## THE INTERNATIONAL TELEGRAPH CONVENTION OF ROME. 1871-1872.

THE third Conference of States interested in the working of the Electric Telegraph, was inaugurated on the 1st of December, 1871, at Rome. The two preceding conferences had been held, the first at Paris, the second at Vienna and there had been assembled meanwhile at Berne, a Special Commission, composed of delegates of the States to settle, subject to the approval of their respective Governments, certain pressing questions affecting an important class of telegraphic correspondence.

At this Commission a question of consequence, more especially to Great Britain, owing to the large number of her private telegraphic undertakings, had been formally decided, viz:—that companies' representing lines of telegraph should be admitted to the Commission with deliberative powers, but without votes. The same important question was one of the first debated at Rome, where the conclusion come to was practically equally satisfactory, the formality of an invitation to each sitting by the President being, however, stipulated for, so that the right of according admission, present and future, should be reserved to the States, the Conference being strictly speaking a Conference of States, and not of Companies. The same plan will probably be pursued at the next Conference, to be held at St. Petersburg, where, according to a courteous intimation from his Excellency General von Lüders, Companies will also be invited to attend.

When the Conferences of Paris and Vienna were held, the telegraphs in this country were all in the hands of private corporations and consequently England was not represented. In 1871 the inland systems of telegraphs were transferred to the state, and the Post Office promptly decided that Great Britain should join the convention. At Rome accordingly Great Britain made formal act of adhesion, and this the last conference will always stand prominently forth as enrolling not the least influential of Western Nations: at the same time the far East also sent its representative, "in order to become enlightened upon the questions of international telegraphy"; and if painstaking attention can achieve that object, M. Shioda will certainly enlighten the Government of Japan, linked up at length with the almost universal telegraph system.

The states sending delegates to the Conference were the following—Austro-Hungary, Belgium, Denmark, France, Germany, Great Britain, and India, Greece, Holland, Italy, Japan, Norway, Persia, Portugal, Russia, Roumania, Servia, Sweden, Switzerland and Turkey.—The Companies represented were fifteen in number, and included, the great lines to America, India, China, Japan, Java, and Australia. The whole of Europe and India were therefore present

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Holland (for her Dutch possessions), Japan, and the companies representing the great oceanic and land lines connecting through Europe the far Eastern with the distant Western World.

America, North and South, have not yet joined the international system, although in Rome it was announced as probable that the American Government would acquire the inland lines, and ultimately, perhaps at St. Petersburgh join the great international telegraphic family.

Each state represented had only one vote; India being, however, allowed a vote as well as Great Britain, the discussions were conducted in French, and the deliberative faculty was pratically unrestricted and depended more upon the powers or the modesty of the representatives than upon the patience of the President. The proceedings were opened by Count Visconti Venosta the Italian Minister of Foreign Affairs: Monsieur E. D'Amico was the first President and on his retirement through ill health Monsieur Brunner de Wattenwyl was chosen to take his place, and continued to preside until the termination of the proceedings, when Count Visconti Venosta again attended, witnessed the signature of the new convention and closed the conference.

It will be seen from the date of the first convention, that of Paris in 1865, that these international agreements are of recent introduction, and as may be supposed they arose out of the growth of the telegraphic system.

Originally each state had its own rules and plans of working, its own method of counting and charging the messages and its own peculiar description of apparatus, the whole of which were of course calculated to secure the benefit and convenience of the state immediately concerned.

As the telegraph extended, however, the wires reached at last the frontiers of the States, and joined those of other countries: in fact, the system once national became international, and immediately that messages began to be interchanged with different countries, the difficulties and confusion caused by the variety of systems became apparent. This naturally led between conterminous States to treaties and arrangements for facilitating telegraphic intercourse, and partially palliated the evils of the independant plan of operations.

Still, the wires were spreading from day to day, and at length an uniformity of system became such an imperative necessity that the Convention of Paris was called to endeavour to arrive at some common basis of action which all the States might adopt. Here, then, were formulated those rules, regulations, and methods of working the wires and counting and charging for telegrams, which together are known as constituting the International Telegraph Convention.

It was natural that after the Paris Convention had been in operation for some time, unforeseen difficulties should become apparent, and growing needs show the necessity of further revision. New rules were wanted to meet new conditions, and hence the Convention of Vienna.

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As one striking result of these Conventions, the Morse instrument and the Hughes type printing apparatus were adopted as the international instruments, so that long circuits of direct wires between the principal cities of Europe became possible, and the boon of what is now known as "direct" communication was conferred upon the public. The basis of the tariff was fixed as "a single message of 20 words," increasing by series of ten at half the charges of the twenty. Uniformity of rates was advocated and carried out, so that in lieu of a separate charge for each town of each country, one rate for all towns in the whole country, and two rates for extensive countries were adopted. This simplification of the charges was, of course, a great boon to the mercantile and general community, and largely increased the number of internal and international telegrams.

These were not the only advantages to the public, brought about by the International convention. The States, for a time, almost competed with one another as to which of them should effect the largest abatements of price, and this unusual emulation led to tariffs which will probably remain unremunerative for some time to come.

The States marched indeed in advance of the public. Before the latter had become sufficiently accustomed to the use of the "telegram," charges were lowered from time to time, and the insufficient augmentation in the number of messages of course failed to make up the deficit occasioned by the reduced charges.

Lines were also unnecessarily increased in number between the same points before the public recourse to the telegraph warranted the augmented outlay, and in some cases steps taken prematurely in the directions indicated have had to be retraced.

Owing to the action of the States, however, rates are universally very moderate, and there is at present such a surplus of accommodation, that in the direction both of tariffs, and of new lines, the public necessities are amply provided for; this is more especially noticeable in the direction of trunk lines for international communication.

The important principle of uniformity once adopted, had to be carried a step further, and many pressing questions awaited their settlement at Rome, of which this was not the least.

Competition, free will, and individual liberty of management had been tried, and found to be impracticable, if there were to be established an International system. How was the public to find its real interests the best cared for? by giving up the rules already made—by allowing International competition to relapse into a system of confusion and difficulty unregulated by international agreement—or by expanding the application of the rules or laws already in force, and extending them by declarations or actual embodiments, so as to embrace all eventualities anticipated.

A convention necessarily pre-supposes rules and regulations, and these inevitably imply restrictions upon individual freedom for the general good.

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Tariffs, for instance, between the same points, of lines traversing countries in similar directions had become conflicting, and various new lines had been opened up the tariffs introduced being dissimilar. Misunderstandings had crept in which it had become necessary to resolve, and some clauses of the Vienna convention had been found to work imperfectly.

Furthermore, Germany had become one great nation for telegraphic purposes, and a new point of departure was necessary.

The States represented at Rome, therefore, whilst giving enlarged facilities in the directions already described to the telegraph intercourse of the world, had individually, for the general good, to submit to curtailments of personal liberty in certain directions essential to the preservation of the International system.

On the whole, the interests of the public have been as carefully provided for at Rome, as at Paris and Vienna.

One of the first proceedings of the convention, was to name three commissions composed of members, one of tariffs, one of regulations, and one of the general laws of the convention proper, and these commissions working on simultaneously and with the Conference, gave to all the questions mooted careful consideration, and the benefit of the supervision of the whole Conference.

A long debate took place upon the question of lines of telegraph, connecting the same points, by wires taking similar directions, competing in price.

General Von Chauvin, the Director General of Prussia, at Vienna, had strongly insisted upon uniformity of price, and emulation in point of excellence: in fact upon any other basis, a telegraph convention becomes an impossibility, because the very essence of the principle of uniformity would be contravened, and the competition and rivalry engendered would occasion disputes, and bitter contests under the influence of which the convention must fall to pieces. The Commission of Berne passed a resolution in favor of uniformity of tariffs, and after full deliberation, the Convention of Rome carried the application of the principle into practice.

At Berne, the rates to India were raised to £4 10s. per single message of 20 words, and were assimilated viâ Turkey, Teheran and Malta. The Conference of Rome, however, reduced the rate from £4 10s. to £4, leaving a slight difference in favor of the Turkish route, inasmuch as, owing to the imperfect working of that route, and the disadvantages it labours under, its management could not be so effective.

This was probably one of the few errors committed by the Conference: the logical consequences of the Convention should have been fully applied, and Turkey would have either improved her system, or have lost the business which, in consequence of her defective arrangements, she was unable to preserve. Any competitive reductions or alterations of tariff were, however, to be met by very stringent measures, and the declarations to this effect safeguarded the uniform principle very completely.

The public in future, if they wish, are to have the right to send messages

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composed in the body entirely of figures, or of letters, and all messages not containing a "comprehensible sense" are to have the letters composing the words added together and are to be divided by five, to give the number of words chargeable. Any remainder of letters less than five is charged as one word. The names and addresses are counted as usual.

Messages written in dictionary words but not necessarily meaning what the words imply, in fact a class of cypher messages, are counted as if composed of ordinary words.

Where a State does not accept messages written in cyphers for internal transmission, such a State, save in given cases of war, or "force majeure," must admit such messages "in transit," the conference thus again recognising and embracing the cosmopolitan character of the ideas brought about by the Convention.

Another important question for the merchant has always been that of the power of selecting the route his message was to follow, and of indicating it. True, this power had not been refused to him before, but he was practically restricted by being made to pay for the privilege. At Rome the payment was abolished, and the power given in an absolute form, the tone of the Conference becoming imperative upon the respect to be paid to the senders wishes.

Extra European lines—that is lines working outside the limits of Europe—were authorised, upon agreement between all the parties interested, to introduce messages of 10 words at a reduced tariff, with a tariff increasing at per word. Seven syllables were declared by the Conference to be the decent telegraphic limit of one word in all languages, and if it chose to exceed these pretty ample proportions, it was to be taxed and made to pay as two words, as a punishment not too great for its inordinate pretensions.

Provision was also made that all despatches "beyond Europe" should in future be registered, and as the administrations are to give the senders receipts for registered messages, the British public, with the aid of the Conference, will be able to procure from the Postal Department, receipts for this class of correspondence.

As heretofore, the indications transmitted free are the place of departure of the despatch, the hour and minute of its acceptance from the sender, the number of words contained within the message, and the date.

Messages intended to finally reach their destination by the intervention of the old slow-going medium of the post, are to be "expedited" by that obsolete system of conveyance without extra charge, unless they pass across a frontier into another State, or their destination lies beyond the sea, when the ordinary tariff becomes payable.

That portion of the public of the globe, too, which goes to sea in ships, and merits careful thought of its interests, is to have its telegrams "semaphored" from coast to ship at a cost of 2 fr. per 20 words.

The Conference, after much discussion, also expressed the view that certain

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questions submitted to the delegates, notably one affecting the neutralisation of submarine cables in case of war, deserved the attention of the Governments—the delegates not conceiving that they had any power to pledge their Governments in this respect, as the question lay in regions beyond the competence of their authority.

Senders of messages are still to be entitled to reimbursement under certain circumstances of the price paid for their messages. There are regulations to insure delivery to the proper persons, as intended by the sender, and provisions of varied character too numerous to be noticed here, but essential to complete the machinery required to make the telegraphs of the world operate in the most beneficial manner for the nations.

Savill, Edwards & Co. have published a translation of the Convention (adopted by the Post Office), and made by Mr. Alfred Brasher, Superintendent of the Indo-European Government Telegraph Department, and as this translation appears to be carefully and correctly done, the public interested in the subject may inform themselves of all clauses affecting their interests.

The Postal Department, and the Indian and German Governments vigorously upheld throughout the discussions of the Conference the main grand principle of uniformity of rules, tariffs, and regulations, and their exertions were crowned with gratifying success.

The States who for the general benefit have submitted to restraints upon their individual action in the direction of international interests, will doubtless for the same reason, insist upon the observance of the Convention, and although perhaps in any particular direction this may cause some little difficulty, the universal advantage derived will more than counterbalance any limited inconvenience occasioned.

The next Conference will be held at St. Petersburg in 1875, but in order to add to the elasticity of the Convention system, in case of any difficulty arising, six of the contracting States may at any time cause an earlier assemblage of the Members, should urgent circumstances call for such a step. Precautions therefore, have been wisely taken against any dead lock.

Thus has terminated the Conference of Rome, and not the least great public lesson it conveys, is that the States of Europe have found one ground, where, notwithstanding their divergent interests, they can meet, amicably discuss, and arrive at uniform methods of treatment of important International interests, affecting intimately the population of almost the entire globe.

W. ANDREWS.

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Mr. Thomas Evans Lundy, who died recently, was a member of the Society of Telegraph Engineers from its commencement. He had been engaged in Telegraphy for many years, but probably will be best remembered by his establishing the School of Telegraphy in the City Road, which still exists, and the "Electric Telegraph Review," a weekly journal that had a very limited existence.

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# JOURNAL

OF THE

# SOCIETY OF TELEGRAPH ENGINEERS.

VOL. I. 1872. No. 2.


The Fourth Ordinary General Meeting, was held on Wednesday, April 10th, 1872, C. W. SIEMENS, Esq., F.R.S., President, in the Chair.

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The Paper read was "ON THE APPLICATION OF THE CALCULATING MACHINE OF M. THOMAS DE COLMAR TO ELECTRICAL COMPUTATIONS," by Thomas T. P. Bruce Warren, Electrician to Hooper's Telegraph Works (Limited) Member of the Society of Telegraph Engineers.

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The following diagram represents a top view of a sixteen figure machine drawn to one-fourth full size. The same illustration and arrangement, of its parts apply to the smaller and larger machines, except the smallest sizes which do not contain the Quotient holes and Effacers. The description here given is taken from an interesting paper by Major-General Hannyngton, of the India Office, which was read before the Society of Actuaries Feb. 27th, 1871. The convenience in retaining the same terms for the parts of the machine concerned in its working, and the completeness of the directions, have tempted me to reproduce his description verbatim.

"The fixed brass plate AA may be called the Face Register or Face, on which numbers expressed by nine or fewer figures may be indicated by the moveable markers *a*. When we desire that any given number should be so indicated, the direction will be to set on that number.



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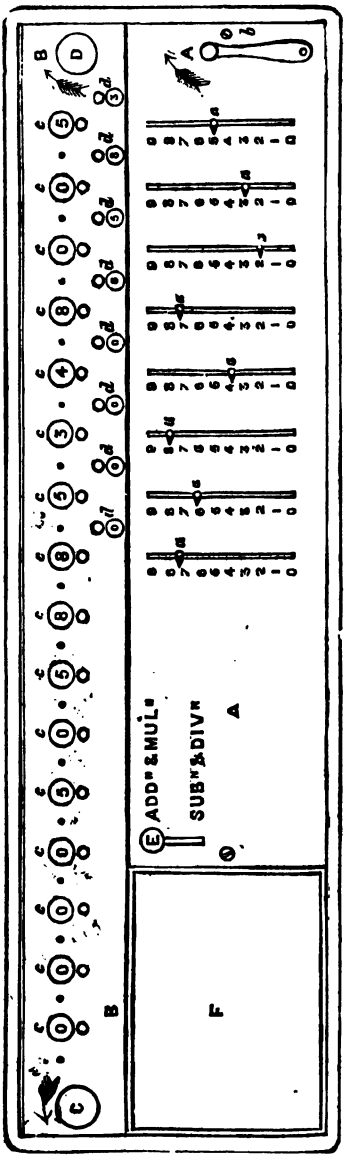
The moveable plate BB we shall call the Sliding Register or Slide, and when we desire that a number be transferred from the face to the slide the direction will be to put up that number. In the diagram the number 76847235 is 'set on,' and the number 505885348005 is 'put up,' while the numbers 6583 appear in the 'quotient holes.' The figures in the upper holes shew the product of the first and last of these numbers.




Sometimes it will be convenient to put up numbers by hand—which may be done by turning the studs which are under the figure holes *c* (sixteen in number in the diagram). These studs are fixed on the axes of the figure disks, which disks turn in either direction, and have the numerals 0 to 9 so arranged on them as to appear, one at a time, in the figure holes. A smaller set of holes *d*, studs and disks (in the diagram nine in number) are placed below the others on the right hand half of the slide, these may be called the '*quotient*' holes, *studs* and *disks*, being as will appear, serviceable chiefly in the operation of division. The smaller holes between the figure holes *c* serve to hold an ivory pin to mark, when requisite, the decimal point, and also to point off the figures in extracting square roots. By turning the milled head C towards the left hand, and the head D towards the right hand, the figures in the holes *c* and *d* respectively will become zeros; these heads may therefore be called *Effacers*. Before commencing any operation, it is necessary to see that all significant figures have been effaced. The button E which slides along

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the slit shown in diagram, may be called the *Regulator*, because as marked on the face its position determines the action of the instrument. The *winch b*, turned by hand, always in one direction, to the right, gives motion to the mechanism. One turn 'puts up' the number that has been 'set on' the face, and if this number be not changed, another turn will put it up again, and so on continuously. Under the winch lies a pin, not shewn in the diagram. This may be called the *Stopping pin*, at which the winch should always be stopped. When the winch is not at the stopping pin, the regulator cannot be moved. Attached to the markers, under the face, is a spring to keep them when in use in their proper place. F is a small plate of ground glass to serve as a writing tablet.

The arrows indicate the directions in which the milled heads and the winch respectively are to be turned.

When using the machine, if the winch *b* be found not to move freely, the plate B B should be lifted up and the winch turned three or four times, after all the markers have been placed to zero. The winch should turn freely and smoothly. A very small quantity of clock oil or refined neat's-foot oil, applied from time to time, is all that is required to keep it in order. The accumulation of dust in the machine may be avoided by keeping it shut up when not in use.

Before turning the handle, care should be taken that the sliding plate is accurately dropped into its proper position; sometimes the regulator, by being pushed too far towards the top, may prevent the teeth of the wheels from catching each other properly when the machine is in action. Inattention to this will frequently lead to incorrect results.

A description of its mechanism appeared in the *Engineer*, May 20, 1870. The only addition I have to make to this is, that the figure disks in the holes *d* (the "quotient holes") are each marked with the numbers 0 to 9 ascending and from 8 to 1 descending, and arranged around the same circle. It is by this that successive additions and subtractions of numbers "set up" are indicated without confusion. The quotient holes shew the number of turns given to the handle, which gives the operator an opportunity of checking his results. When effacing the figures, either in the quotient holes or in the larger holes, the sliding plate should be lifted up, and when we desire to put up a number by turning the figure disks, the same precaution must be taken.



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As it is generally convenient to be able to refer to the constants which are noted for any calculations, I replace the glass tablet with pieces of paper cut to the same size.

The mechanism for carrying from one set of figures to another deserves special notice. The following description is given by Edward Sang, Esq., F.R.S.E., in a lecture before the Actuarial Society of Edinburgh, on "Mechanical Aids to Calculation":—*

"Under each of the slits is a cylinder, which makes a complete revolution for every turn of the handle. On the surface of each cylinder are placed nine parallel bars, or, as we may call them, elongated teeth, which are to work the teeth of the counting wheels. The lengths of these bars are equi-different, so that at one part of the cylinders the whole nine are ready to act, at the next place eight, and so on. The markers, when any number is set up, can thus only catch the number of teeth to which it is placed. The counting wheel is moved upon a square axis, and by means of the markers can be brought opposite to any desired part of the cylinder."

"If we bring the counting wheel so as to be acted on by four bars, one turn of the cylinder will cause an addition of four, and each succeeding turn will cause a new addition of four. Now, for each of the indices, that is for units, tens, hundreds, and so on, we have a special cylinder, and therefore if we set the counting wheels to specified digits, and turn each of the cylinders once round (for the present we shall suppose once in succession) we shall have added the specified number to the previous indication."

"If we do this for one cylinder after another, some considerable time will be required. The contrivance for economising that time is exceedingly ingenious in Thomas's machines. He causes all the cylinders to be actuated at once by the working handle, so that all the additions go on *nearly at once.* If the additions were made all at once, a confusion would of necessity arise in the carrying. He therefore makes the index wheels entirely independent of each other, and arranges the carrying in another way. On each index wheel there is fixed a stud to come in contact with a lever whenever the indicator passes from 9 to 0, and so as to push this lever aside, and a detent is provided to keep this lever back after the stud has passed onwards. This lever brings into action the carrier fixed on the axis, and this carrier only acts after the addition by the bars has been

* *Journal of the Institute of Actuaries*, Vol. 16, part 4.

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completed. Thus by arranging the cylinders one tooth in arrear at each step the carrying is completely effected, and the whole addition completed by one turn of the handle."

If we put up 1 in the 9th figure hole, and place the marker in the unit's place on the fixed plate at 1, and place the regulator at subtraction, we shall, on turning the handle slowly, observe the progressive action of this part of the mechanism. The operation is simply to subtract 1 from 100,000,000, when we get 99,999,999 in the dividend holes. This simple operation is given as a test of the completeness of a machine.

When we require to set up any number on the fixed plate, it will be best, in nearly all cases, to begin at the left hand or units' place. In transferring figures from the fixed plate to the moveable plate, if we require to put up more figures than can be indicated on the face, the slide may either be moved out so far as to enable us to put up the remaining figures to the left by hand, or if left in its ordinary position the front figures may be similarly supplied.

The calculations which are involved in the testing of Telegraph Cores and Cables although simple and easily systematized, become irksome and monotonous even to the most ardent admirer of figures. There are but few expedients available in reducing the number of these calculations, and these are, when testing the different sections of Core, to take the observations at one uniform temperature, and to have these sections of the same linear measures, but even then the reductions for Specific Conductivity, Capacity, and Dielectric Resistances offer the same labour to the computer, for although the sections may be uniform in their linear dimensions, their electrical values may be found to vary more or less. A table of Specific Conductivities could be calculated for all the possible or admissible variations in the resistances of a Specified Conductor, but the calculations for Capacity and Dielectric Resistance cannot be reduced to tables within reasonable dimensions, as the constants by which they are determined are liable to extensive variation. There are other preliminary calculations as constants, shunts, &c., which in a general way of testing are also numerous and varied. The rapidity with which ordinary Arithmetical operations are performed by this machine, is attended with results which are strictly and mechanically accurate.

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Each of the tables accompanying this paper represents one hour's work on the Machine at full power, the result being recorded only with as many figures as in practice will be required.

The operations which in the usual way are performed by logarithms, are performed by the machine with the natural numbers or their reciprocals, so that the time in looking up logarithms is saved, and if required, a result can be obtained in nearly the same time, true either to 4 or 10 figures, or to the full extent of the powers of the machine.

I do not propose to deal separately with the methods of performing the operations of Addition and Subtraction, Multiplication and Division, but to give a few illustrations in working out electrical problems, and in which these operations are combined.

Let it be required to find the multiplying power of a shunt of 5 units, used with a Galvanometer of 5762 units.

We proceed thus:—5762 is first "set up" on the fixed plate A A, and turning the regulator to addition, by one turn of the handle we reproduce the number on the slide B B above it, at the same time the figure 1 appears on the same plate in the quotient holes under the figure 2. The figure 5 is next set up in the unit's place, and the other indices or markers are brought back to zero; another turn of the handle adds 5 to 5762, which is already put up, so that we have 5767 for dividend. The regulator is now turned to division, the figures in the quotient holes effaced, and the sliding plate moved outwards to the right, so that the figure 5 is immediately over and above the 5 in the fixed plate last set on, one turn of the handle divides the first figure of the dividend, and we find 1 in the quotient hole immediately over the handle, and 767 on the slide for remainder. The slide is now moved inwards one notch, so that the 7 is over the 5, and the handle turned once more, when the figure 1 will appear in the next quotient hole, and 267 will be left as remainder; the plate is again moved one notch further inwards, and the handle turned 5 times, when the figure 5 will appear in the next quotient holes, and 17 on the moveable plate as remainder. This plate is moved in another notch, and the handle turned three times, when the quotient holes will shew the figures 1153, and 2 will be left as remainder on the moveable plate.

If the slide had been moved out previously to commencing the operation, the division could have been carried one figure further, nd so have exhausted the dividend, we should then have 5672,

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followed with as many 0s as there had been notches in the slide moved outwards; a decimal point should then be placed after the figure 2 before going further, the 5 should then be added, and the division carried on as before, the quotient holes will then shew the figures 1153·4, and the dividend plate will contain all 0s.

As multiplication is performed with much greater rapidity than division, it is preferable, in most cases, to multiply the dividend by the reciprocal of the divisor than to divide in the ordinary way; for instance, we should set up on the fixed plate 5767, and, turning the regulator to multiplication, give 2 turns of the handle, ·2 being the reciprocal of 5; when on the moveable plate will appear the product 11534. The rules for supplying decimal points will shew at once that this should read 1153·4.

Again, let a resistance of 25·7 units be used as a shunt to the same galvanometer; we move the plate either out to its full extent, or so far out as to obtain the number of quotient holes to the right of the fixed plate as may be required for the result; we set up 5762, and by one turn of the handle, the regulator being to addition, the figures will appear on the dividend plate, a decimal point is placed after the figure 2, and the slide moved inwards one notch; 257 is now set up on the fixed plate, when another turn of the handle adds it to 5762, so that 5787·7 will appear as dividend; the slide is now moved out, so that the first three figures of the dividend, 578, stand immediately over 257 on the fixed plate, the figures in the quotient holes are effaced, and the regulator being turned to division we grind out the result as before (225·2023). In pointing off the decimal figures we must not forget that the divisor is 25·7.

The decimal points need not be used, provided it is understood where they belong, which by a little practice is readily acquired.

When dividing, the conditions to which attention should be directed are,—that the figures on the dividend plate, *which are over the divisor*, must appear in value greater than the divisor, so that the slide must be moved inwards until the number on it will contain the divisor. Care should be taken when multiplying or dividing, but more especially when dividing, that the quotient holes are all at 0s.

Before commencing the operation of division, we must see that we have a sufficient number of quotient holes to the right of the handle as to give the desired number of figures in the quotient. In multiplying

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the quotient holes supply a check, inasmuch as they indicate the number of turns given to the handle, and consequently the number of times which the multiplicand has been multiplied.

In calculating the multiplying power of the 25·7 units shunt we may have set up 5787·7, and multiplied by the reciprocal of 25·7 (=·03891051). This is performed by placing the regulator to multiplication, and giving one turn of the handle, moving the slide out one notch and turning the handle five times, putting the slide out two more notches and giving one turn, and so on for the other figures; the result on the dividend plate will be 225·202358727, the decimal point being supplied according to the usual rules. When using the reciprocals of numbers in this or for similar operations, the first three or four significant figures will be sufficient for almost any practical purpose.

When the slide is moved outwards, we effect the multiplication of any number which is to appear on it by 10, 100, 1,000 and so on, and conversely in placing the slide backwards, we effect the division by 10, 100, 1,000, &c.

In performing multiplication it may be worth pointing out, that when the multiplier consists of high figures, the labour of multiplying may be considerably reduced by combining with it the operation of division, thus to multiply any number by 999, we move the dividend plate out to the fourth notch, when by one turn of the handle, with the regulator at multiplication, we multiply the number set up by 1,000, we have now to turn the regulator to division, and move the dividend plate backwards to its original position, when by one turn of the handle we subtract 1-1,000th part of the result, and obtain the same product on the slide as we should have obtained by multiplying in the ordinary way, hence by two turns of the handle we perform the same work as would be required by 27 turns:—

Thus, 5762 × 1000 = 5762000
Subtract 1-1000th = 5762

5756238 = 5762 × 999

In order to obtain a clear conception of the *modus operandi* of the machine, it is necessary to bear in mind that the four elementary rules of arithmetic, addition, subtraction, multiplication, and division are reducible to the fundamental principles of addition and subtraction.

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It does not appear that the machine can help us very much, if indeed at all, in the calculations for the derived circuit, for we should have to transfer the several products from the slide to the face to be multiplied by the succeeding resistances. The following abbreviated method of adding together the reciprocals of the resistances, and then finding the number of which this sum is the reciprocal, does not appear to be capable of being presented to the machine with any important saving of time or trouble, unless perhaps, for the determination of the last result, in which case unity is to be set up on the slide, and the sum of the reciprocals on the face, when we have merely to perform the division. Considering that it is much easier to find from the tables the reciprocals corresponding to numbers, than it is to find a number corresponding to any given reciprocal, it is doubtful whether a slight advantage might not exist on the side of the machine. But an unquestionable advantage must be claimed for the machine in calculating reciprocals, and to which I shall refer presently.

Another method is open to us for calculating the resistance of a derived circuit, and which although it does not admit of machine assistance, may be worth noting here as it gives us a conception in forming tables of reciprocals.

Since any number and its reciprocal have the same logarithm, but with contrary signs; and the sum of the logarithm of any number and its complement, is equal to O., the co-logarithm of any sum of resistances will be the logarithm of the resulting resistance. Let 4 and 8 represent the resistances in parallel circuit:—

$$\text{Then } \frac{4 \times 8}{12} = 2{\cdot}666 \quad \text{or}$$

$$\text{reciprocal of } 4 = {\cdot}25$$

$$\text{,, } 8 = {\cdot}125$$

$$\text{Log. } {\cdot}375 = \bar{1}{\cdot}57403$$

$$\text{Colog. } = 0{\cdot}42597 = \text{log. of } 2{\cdot}666.$$

Although the machine is not capable of shewing the product of more than two factors at once, it will give the sum of the products of several factors without shewing the products themselves separately, this should be of great utility in calculating areas which are generated by curves of the second or higher orders, as well as problems contained in the ordinary mensuration of solids and conic sections. Its more immediate application to Telegraphic Engineering will be in finding

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the contents of cable tanks, tonnage of ships, ascertaining the weight of materials composing a cable, the specific gravity of a cable from the known weights, and specific gravities of the materials respectively composing it, and so on. Tensile strength of iron wires, weights and diameters of iron, and copper wires, dielectric, &c. The constants in these latter cases must be determined from the law of variation indicated in each particular case.

As these calculations do not fairly come within the province of this paper, but are nevertheless of interest, I shall merely submit to you a few tables calculated by the machine for these latter cases, all that is necessary is to put on the constant in each particular case, and to multiply by the square of the diameters.

WEIGHTS OF COPPER WIRES PER NAUTICAL MILE.

| In. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| ·10 | 183 | 186 | 190 | 194 | 197 | 201 | 205 | 209 | 213 | 217 |
| ·11 | 221 | 225 | 229 | 233 | 237 | 241 | 245 | 250 | 254 | 258 |
| ·12 | 263 | 267 | 271 | 276 | 280 | 285 | 289 | 294 | 299 | 303 |
| ·13 | 308 | 313 | 318 | 323 | 327 | 332 | 337 | 342 | 347 | 352 |
| ·14 | 358 | 363 | 368 | 373 | 378 | 383 | 389 | 394 | 399 | 405 |
| ·15 | 411 | 416 | 421 | 427 | 432 | 438 | 444 | 449 | 455 | 461 |
| ·16 | 467 | 473 | 478 | 484 | 490 | 496 | 502 | 508 | 514 | 521 |
| ·17 | 527 | 533 | 539 | 546 | 552 | 558 | 565 | 571 | 577 | 584 |
| ·18 | 591 | 597 | 604 | 610 | 617 | 624 | 630 | 637 | 644 | 651 |
| ·19 | 658 | 665 | 672 | 679 | 686 | 693 | 700 | 707 | 714 | 721 |
| ·20 | 730 | 736 | 743 | 751 | 758 | 766 | 773 | 781 | 788 | 796 |
| ·21 | 805 | 811 | 819 | 826 | 834 | 842 | 850 | 858 | 866 | 874 |
| ·22 | 883 | 890 | 898 | 906 | 914 | 922 | 931 | 939 | 947 | 956 |
| ·23 | 965 | 972 | 981 | 989 | 998 | 1,006 | 1,015 | 1,023 | 1,032 | 1,041 |
| ·24 | 1,051 | 1,058 | 1,067 | 1,076 | 1,085 | 1,094 | 1,103 | 1,112 | 1,121 | 1,130 |
| ·25 | 1,139 | 1,148 | 1,157 | 1,166 | 1,176 | 1,185 | 1,194 | 1,203 | 1,213 | 1,222 |

If the figures in the column (in.) be divided by 10 we have merely

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to deal with the two figures towards the left hand of the number opposite to it as decimals—thus a wire ·025 = 11·41 lbs. ·0255 = 11·85 lbs.

This remark applies also to the other tables in which the variation is as $D^2$. Tables involving the second power of a function, and in which the second differences are constant, can be computed by simply adding on these differences to the value already on the face. This method is more rapid than multiplying by $D^2$.

## TABLE,

Shewing the Breaking Strain of Iron Wires of different sizes, from the data "that the Breaking Strain varies as the Squares of the Diameters and is equal to 1 ton per square inch, and uniform for all diameters."

| In. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | .7854 | .8012 | .8171 | .8332 | .8495 | .8659 | .8825 | .8992 | .9161 | .9330 |
| 1.1 | .9503 | .9676 | .9851 | 1.0028 | 1.0206 | 1.0386 | 1.0567 | 1.0750 | 1.0935 | 1.1121 |
| 1.2 | 1.1310 | 1.1498 | 1.1689 | 1.1881 | 1.2075 | 1.2271 | 1.2468 | 1.2667 | 1.2867 | 1.3069 |
| 1.3 | 1.3273 | 1.3477 | 1.3684 | 1.3892 | 1.4102 | 1.4313 | 1.4526 | 1.4740 | 1.4956 | 1.5174 |
| 1.4 | 1.5394 | 1.5615 | 1.5837 | 1.6061 | 1.6286 | 1.6502 | 1.6730 | 1.6961 | 1.7192 | 1.7425 |
| 1.5 | 1.7672 | 1.7908 | 1.8146 | 1.8385 | 1.8619 | 1.8869 | 1.9113 | 1.9359 | 1.9608 | 1.9856 |
| 1.6 | 2.0106 | 2.0358 | 2,0612 | 2.0867 | 2.1124 | 2.1383 | 2.1642 | 2.1904 | 2.2167 | 2.2432 |
| 1.7 | 2.2698 | 2.2966 | 2.3235 | 2.3506 | 2.3779 | 2.4053 | 2.4329 | 2.4606 | 2.4885 | 2.5165 |
| 1.8 | 2.5447 | 2.5730 | 2.6016 | 2.6302 | 2.6591 | 2.6880 | 2.7172 | 2.7465 | 2.7759 | 2.8055 |
| 1.9 | 2.8353 | 2.8652 | 2.8953 | 2.9255 | 2.9559 | 2.9865 | 3.0172 | 3.0481 | 3.0791 | 3.1103 |
| 2.0 | 3.1416 | 3.1731 | 3.2047 | 3.2366 | 3.2685 | 3.3006 | 3.3329 | 3.3654 | 3.3980 | 3.4307 |
| 2.1 | 3.4636 | 3.4967 | 3.5299 | 3.5633 | 3.5968 | 3.6305 | 3.6644 | 3.6984 | 3.7325 | 3.7668 |
| 2.2 | 3.8013 | 3.8359 | 3.8707 | 3.9056 | 3.9407 | 3.9760 | 4.0114 | 3.0470 | 4.0827 | 4.1186 |
| 2.3 | 4.1548 | 4.1909 | 4.2272 | 4.2638 | 4.3004 | 4.3373 | 4.3743 | 4.4114 | 4.4487 | 4.4862 |
| 2.4 | 4.5239 | 4.5616 | 4.5995 | 4.6376 | 4.6759 | 4.7143 | 4.7528 | 4.7915 | 4.8304 | 4.8695 |
| 2.5 | 4.9088 | 4.9481 | 4.9876 | 5.0273 | 5.0671 | 5.1071 | 5.1472 | 5.1875 | 5.2279 | 5.2685 |

If the figures in the column (in.) be divided by 10, we move the decimal point two places further to the left, thus a wire ·1″ would sustain ·007854 tons, ·105″ ·008659 &c.

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The numbers in this table multiplied by any specified breaking strain in tons per square inch, will give the breaking strain to the required standard.

## TABLE OF WEIGHTS (IN LBS.)

Per Nautical Mile of a material whose Sp. Gr. is 1. The number corresponding to a given diameter multiplied into the Sp. Gr. of any material will give the weight per Nautical Mile of that material.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | 2,074 | 2,116 | 2,158 | 2,200 | 2,243 | 2,286 | 2,330 | 2,374 | 2,419 | 2,464 |
| 1.1 | 2,509 | 2,555 | 2,601 | 2,648 | 2,695 | 2,743 | 2,791 | 2,839 | 2,888 | 2,937 |
| 1.2 | 2,986 | 3,036 | 3,087 | 3,138 | 3,189 | 3,241 | 3,293 | 3,346 | 3,399 | 3,452 |
| 1.3 | 3,505 | 3.560 | 3,613 | 3,668 | 3,724 | 3,780 | 3,836 | 3,892 | 3,949 | 4,007 |
| 1.4 | 4.065 | 4,121 | 4,182 | 4,241 | 4,300 | 4,360 | 4,421 | 4,481 | 4,543 | 4,604 |
| 1.5 | 4,666 | 4,729 | 4,791 | 4,855 | 4,918 | 4,982 | 5,047 | 5,112 | 5,177 | 5,243 |
| 1.6 | 5.309 | 5,376 | 5,443 | 5,510 | 5,578 | 5,646 | 5,715 | 5,784 | 5,853 | 5,923 |
| 1.7 | 5,993 | 6,064 | 6,135 | 6,207 | 6,279 | 6,351 | 6,424 | 6;496 | 6,571 | 6,645 |
| 1.8 | 6,719 | 6,794 | 6,869 | 6,945 | 7,021 | 7,098 | 7,175 | 7,252 | 7,330 | 7,408 |
| 1.9 | 7,487 | 7,566 | 7,645 | 7,725 | 7,805 | 7,886 | 7,967 | 8,048 | 8,130 | 8,213 |
| 2.0 | 8,295 | 8,379 | 8,462 | 8.546 | 8,631 | 8,715 | 8,801 | 8,886 | 8,972 | 9,059 |
| 2.1 | 9,146 | 9,233 | 9,321 | 9,409 | 9,497 | 9,586 | 9,676 | 9,766 | 9,856 | 9946 |
| 2.2 | 10,037 | 10,129 | 10,221 | 10,313 | 10,406 | 10,499 | 10,592 | 10,686 | 10,781 | 10,876 |
| 2.3 | 10,971 | 11,066 | 11,162 | 11,259 | 11,356 | 11,452 | 11,551 | 11,649 | 11,747 | 11,846 |
| 2.4 | 11,945 | 12,945 | 12,145 | 12,246 | 12,346 | 12,448 | 12,550 | 12,652 | 12,755 | 12,858 |
| 2.5 | 12,962 | 13,066 | 13,170 | 13,275 | 13,380 | 13,485 | 13,591 | 13,700 | 13,804 | 13,912 |

## TABLE OF WEIGHTS (IN LBS.)

Per Statute Mile of a Material whose Sp. Gr. is 1. The number corresponding to a given diameter multiplied into the Sp. Gr. of any material will give the weight per Statute Mile of that material.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1·0 | 1,799 | 1,835 | 1,872 | 1,908 | 1,946 | 1,983 | 2,021 | 2,060 | 2,098 | 2,137 |
| 1·1 | 2,177 | 2,216 | 2,257 | 2,297 | 2,338 | 2,379 | 2,420 | 2,463 | 2,505 | 2,547 |
| 1·2 | 2,590 | 2,634 | 2,677 | 2,722 | 2,766 | 2,810 | 2,856 | 2,901 | 2,947 | 2,994 |
| 1·3 | 3,040 | 3,087 | 3,134 | 3,182 | 3,230 | 3,279 | 3,327 | 3,376 | 3.426 | 3,476 |
| 1·4 | 3,526 | 3,576 | 3,627 | 3,679 | 3,730 | 3,782 | 3,835 | 3,887 | 3,940 | 3994 |
| 1·5 | 4,048 | 4,102 | 4,156 | 4,211 | 4,266 | 4,322 | 4,378 | 4,434 | 4,491 | 4,548 |
| 1·6 | 4,605 | 4,663 | 4,721 | 4,780 | 4,838 | 4,898 | 4,957 | 5,017 | 5,077 | 5,138 |
| 1·7 | 5,199 | 5,260 | 5.322 | 5,384 | 5,446 | 5,509 | 5,572 | 5,636 | 5,700 | 5,764 |
| 1·8 | 5,828 | 5,893 | 5,959 | 6,024 | 6,090 | 6,157 | 6,224 | 6,291 | 6,358 | 6,426 |
| 1·9 | 6,494 | 6,563 | 6,632 | 6,701 | 6,770 | 6,840 | 6,911 | 6,981 | 7,052 | 7,124 |
| 2·0 | 7,196 | 7,268 | 7,340 | 7,413 | 7,486 | 7,560 | 7,634 | 7,708 | 7,783 | 7,858 |
| 2·1 | 7,933 | 8,009 | 8,085 | 8,161 | 8,238 | 8,315 | 8,393 | 8,471 | 8,549 | 8,628 |
| 2·2 | 8,707 | 8,786 | 8,866 | 8,946 | 9,026 | 9,107 | 9,188 | 9,270 | 9,351 | 9,434 |
| 2·3 | 9,516 | 9,599 | 9,682 | 9,766 | 9,850 | 9,934 | 10,019 | 10,105 | 10,190 | 10,276 |
| 2·4 | 10,362 | 10,448 | 10,535 | 10,622 | 10,710 | 10,798 | 10,886 | 10,975 | 11,064 | 11,153 |
| 2·5 | 11,243 | 11,333 | 11,424 | 11,514 | 51,606 | 11,697 | 11,789 | 11,882 | 11,974 | 12,067 |

Not only is the machine capable of shewing the sum of several factors, but I have found that it will also give us the difference

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between two factors at once on the slide, and in calculating the weights of conductor and dielectric per mile, when the diameters are given, the following simple method gives satisfactory results.

Set on the Face AA the specific gravity of the dielectric, and multiply by the number opposite the diameter corresponding to the core, the result on the slide will be the weight per mile of a solid core of the material, turn the regulator to division and multiply the number still left on the face by the number standing opposite to the diameter corresponding to the conductor, the result now on the slide will be the weight of a solid core of dielectric, less the weight of a solid core equal in bulk to the conductor. For the weight of the conductor we may either refer to the table or set on the number opposite its diameter and multiply by its specific gravity.

Similarly as General Hannyngton has observed, "a series of addends and subtrahends, arranged in any order of succession, may be summed by attending to the signs, and placing the regulator accordingly. In such the occurrence of an intermediate negative value will not embarrass the action of the machine, or interfere with the exhibition on the slide of a final positive result. But if the sum of the subtractive quantities exceed that of the additive quantities, the result will shew one or more superfluous figures, nines, on the left of the slide. These nines must be rejected, and the complements of the other figures taken, thus from 94765 take 181983, the result will be 9999912782, which represents 87218."

Now in dealing with subtractive products, the only difference is that when the subtractive quantities are greater than the products on the slide, we obtain a number of figures, nines, which we have to reject, and to prefix a minus sign to the remaining figures on the slide.

Following upon this, it is evident that the summation of series, either with increasing or decreasing differences is within the range of its performance, and in calculating percentage values, squares and cubes of numbers, has special interest.

Within the powers of the machine, it may be worth pointing out, are the calculations of logarithmic tables, reciprocals, and extraction of square roots. General Hannyngton has shewn that trigonometrical problems may be solved by it with rapidity when the angular functions are of one denomination.

The extraction of square roots may be best described in an illustration, and we will therefore extract the square root of 8,97,65,00,00.

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This number is put up on the slide and pointed off with the ivory pins into pairs. The regulator is turned to division, the markers placed to zero, and the quotient figures effaced. Now, as there are five figures in the root, the slide is moved outwards so as to have this number of quotient holes to the right of the handle, when everything is now ready for operation. The nearest square root to 8, is 2; we then move the marker along the slit, on the fixed plate, under the figure 8 to the number 2, and give two turns of the handle, when this number will appear in the first quotient hole, and leave 497 &c. remainder, the slide is moved in one notch, the figure 2+2=4, so that the marker is moved to 4, which will be contained 9 times in 49. The marker in the second slot is placed at 9, and the handle turned 9 times when 9 will appear in the new quotient hole, and 56 will be left as remainder of the second pair or set of figures, the slide is again moved in one notch, the last number 9 on the slide doubled, when the markers already set on are moved to 5 and 8, the next root again being 9; this number is indicated by the marker in the 3rd slot, and the handle turned 9 times, when 9 will appear in the third quotient hole, and 3 will be left as remainder, the slide is moved in again one notch, the last figure on the face doubled, when the markers should indicate 598; 6 being the next root, this number is set on and the handle turned 6 times, when 6 will appear in the quotient holes, and 4 will remain out of the 3rd set of figures on the slide, the last figure set on is again doubled, so that 5992 is indicated on the face, and the slide moved in, when we find the dividend less than the divisor, so that the next number of the root is 0. The root is, therefore, 29960 and 48400 is left on the slide as remainder.

The following method may also be interesting. The theory of this process depends on the following theorems in arithmetical progression.

If the first term of a series be 1, and the difference 2, the sum of any number of terms composing this series, will be equal to the square of the same number of terms, thus; 1+3+5+7+9+&c. and the last term of the series increased by unity, will give double the number of terms in the series.

To extract the square root of 2209 by second differences, we proceed thus:—This number is put up on the slide, the regulator turned to division, and the number divided into pairs as before, and the slide moved outwards so as to have 2 quotient holes to the right. From the first set of figures we subtract successively 1, 1+2=3, 3+

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2=5, 5+2=7, this number being greater than the number on the slide, we move it inwards one notch, the figure 7 is changed to 8 on the face, and we commence again in the second slot by setting up as before, when the subtractive figures are 81, 83, 85, 87, 89, 91, (the first figure being altered from 8 to 9) and 93, when the figures on the quotient disks will be 47, and no remainder left on the slide.

The following method of obtaining the continuous squares of numbers, depends upon the rule, that:—

If the difference between any two numbers be small when compared with either of them, the ratio of their squares may be obtained by doubling this difference; that is, if $x$ be small as compared with $a$, instead of writing $(a+x)^2=a^2+2ax+x^2$, we may say that $(a+x)^2=a^2+2a+2$, when the difference is 1:—so that if any high number be set up on the face and multiplied by itself, we shall obtain the square of that number on the slide, by moving the marker in the units' place another figure in advance, and giving two turns of the handle we add twice the original number, plus 2, to the number already on the slide. Now, if we do this for a great number of times without rectifying the result, the error will exceed the limits of admissibility, and, therefore, the values of $x^2$ should be calculated and the correction added, say at every tenth calculation.

By assimilating this formula to the cubes and higher powers of numbers, the error increases much faster. But in this way we can perform successive involutions without the aid of a second machine, and which is not without importance when the increments are small.

I am indebted to General Hannyngton for the following useful method for obtaining the continuous squares of numbers:—

Putting $\Delta$ for the difference between any two consecutive numbers, we find $\Delta n^2=2n+1$, so that we first set up on the face AA any number $n$, the product of which when multiplied by itself will appear on the slide BB; we then make the figures on the face equal to $2n+1$, when by one turn of the handle the next square will appear. By afterwards setting on the continuous difference 2, we shall obtain the squares successively of the following numbers; thus, if we set up 7201 and multiply by itself, the slide will shew 51854401, and 7201 will also appear in the quotient holes, the markers are moved to 14403 (which is equal to $2n+1$) and by another turn of the handle we obtain the square of 7202, we move the marker in the units' place to 5, when the figures on the face will be equal to 7202+2+1, when

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another turn of the handle will give the next square, $n$ being the number, the square of which has last appeared on the slide.

If the summation of third differences is made on one machine, and transferred to the face of a second machine, we can rapidly obtain the successive cubes of numbers.

In this way we could extend considerably the squares and cubes of numbers, beyond those contained in Barlow's tables, with complete accuracy.

In shewing how to construct tables of reciprocals, I may quote from the notes on the construction of a table of reciprocals by Lieut.-Col. Oakes, inasmuch as this extensive table was re-computed on the machine by General Hannyngton.* This table contains the reciprocals of all numbers to 100,000 with their differences, so that from these tables we may obtain the reciprocals of numbers as far as 10,000,000. In these tables a peculiar advantage is met with; that the decimal point is not supplied, so that the reciprocals are general whether the number in hand be a decimal or not, the decimal point is therefore to be supplied by the computer according to the value under consideration.

CONSTRUCTION OF TABLES OF RECIPROCALS,
By LIEUT-COL. OAKES, A.I.A.

| Numbers. | | Logs of Diffs. | Nat. Nos. of Diffs. | Reciprocals. | Reciprocals of the Half and Quarter Nos. | Numbers. | |
|---|---|---|---|---|---|---|---|
| | 62501 | .2041130 | | | | | |
| | 62500 | 2041200 | | .00001600 | .00003200 | | |
| | Diffs of Logs. | 4082330 | | .00000000 | .00006400 | | |
| 62499 | 139 | 2469 | 256004 | 0256004 | | | |
| 98 | 139 | 2608 | 12 | 0512016 | 1024032 | 31249 | ½ No. |
| 97 | 139 | 2747 | 20 | 0768036 | | | |
| 96 | 139 | 2886 | 29 | 1024065 | 2048130 | 31248 | ½ No. |
| 95 | 139 | 3025 | 37 | 1280102 | 4096260 | 15624 | ¼ No. |
| 94 | 139 | 3164 | 45 | 1536147 | 3072294 | 31247 | ½ No. |
| 93 | 139 | 3303 | 53 | 1792200 | | | |
| 92 | 139 | 3442 | 61 | 2048261 | 4096522 | 31246 | ½ No. |
| 91 | 139 | 3581 | 70 | 2304331 | 8194044 | 15623 | ¼ No. |
| 90 | 139 | 3720 | 78 | 2560409 | 5120818 | 31245 | ½ No. |

* These tables may be obtained at Messrs. F. & N. Spon's, Charing Cross.

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"Beginning, suppose with the reciprocal of 62500, we write in the right hand margin the complement logarithms of 62500 and 62501, each to 7 places, and without indices. The sum of these is an initial value, to which adding the differences of the logs. of 62499 and 62501, or, in general, the difference of the logs. of $(n-1)$ and $(n+1)$, we readily obtain the logarithms of the difference required, and of the successive differences. The numerical differences being then taken out, the reciprocals of the numbers are obtained by summation."

By the machine it is evident that the variable differences may be set on, and the summation performed faster than the simple addition could be carried out by hand.

In certain cases we require the Napierian Logarithms of numbers which are not included in any published table. These may be calculated by setting on the face AA the modulus 2·3025851, and multiplying by the common logarithms.

In this way the Napierian Logarithms of $\frac{C}{c}$ have been calculated.

Hutton's Mathematical Tables contain the Napierian Logarithms of fractional numbers from 1, increasing by 0·1 to 10·0, which no doubt may prove serviceable in some cases for obtaining Dielectric Resistances from loss of charge, and for calculating the values of $\frac{D}{d}$ in Sir William Thomson's formula for speeds.

A little reflection will shew that 1·01 and 1·02 have a difference in their logarithms, which is so great as to comprehend nearly all conceivable values between 1 and 2, so that we must look for an extension of this table as regards the number of figures after the decimal point, if we desire to apply them.

In extending this table it is obvious that the multiplication of the modulus into the different denary logarithms would be a somewhat tedious operation.

The following simple methods given in Hutton's tables are admirably adapted for machine calculation in obtaining Napierian logarithms by differences, with a rapidity which could hardly be surpassed by an expert mental computer.

1st. When the given number is between 1 and 10.

From the given number subtract the next less tabular number, divide the remainder by the said tabular number, increased by half the remainder, add the quotient to the said tabular number, and the sum will be the logarithm of the number proposed.



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In the table here given of Napierian Logarithms we take the logarithm of 1·03, which in Hutton's table = 0.0295588; and we wish, we may suppose, to tabulate these logarithms to differences of .001, &c.

NAPIERIAN LOGARITHMS.

| Nat. Nos. N | ½ Diffs. δ | Logarithms. | $\frac{1}{N}+\delta$ | Nat. Nos. N | ½ Diffs. δ | Logarithms. | $\frac{1}{N}+\delta$ |
|---|---|---|---|---|---|---|---|
| 1.030 | | 0.295588 | | 1.0300 | | 0.029588 | |
| 31 | .0005 | .0305292 | .000970 | 11 | .00055 | .0306262 | .0010674 |
| 32 | 10 | 314987 | 19399 | 12 | 60 | 07222 | 11654 |
| 33 | 15 | 324672 | 29084 | 13 | 65 | 08202 | 12614 |
| 34 | 20 | 334347 | 38759 | 14 | 70 | 09171 | 13583 |
| 35 | 25 | 344017 | 48426 | 15 | 75 | 10140 | 14552 |
| 36 | 30 | 353671 | 58088 | 16 | 80 | 11109 | 15521 |
| 37 | 35 | 363319 | 67781 | 17 | 85 | 12079 | 16491 |
| 38 | 40 | 372957 | 77369 | 18 | 90 | 18048 | 17460 |
| 39 | 45 | 382587 | 86999 | 19 | 95 | 14017 | 18429 |
| 40 | 50 | 392206 | 96618 | 20 | .00100 | 14987 | 19899 |

From this table it is obvious, that by putting up the initial Log.$_\epsilon$ on the slide and summing the reciprocals for the successive values $N+\delta$, we may grind out a table of Napierian Logarithms as fast as we please. For this purpose, Oakes' tables will be found highly convenient.

We set on the plate 1·03 × ·0005 = 1·0305, and on the slide we put up 1, drawing the slide out previously, so as to obtain a sufficient number of quotient holes in the result, and perform the division. The result is recorded, and the operation repeated for the following logarithms; the quotient added to the log.$_\epsilon$ of 1·030 will be the log.$_\epsilon$ of 1·031, &c., &c.

2nd. When the number exceeds 10—

We find the logarithm as in the first case, supposing all the figures after the first to be decimals, then to that logarithm add 2·3025851 multiplied by the index of the power of 10, according as the given number contains 2,3,4, &c. integers: thus,

$\text{Log}_\epsilon$ 1031 = 0·0395292

Add 2·3025851 = 2·3331143 = log. 10·31

Add 3 × 2·3025851 = 4·6356994 = „ 103·1

Add 3 × 2·3025851 = 6·9382845 = „ 1031

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So that, as Hutton's Tables contain the logarithms of the first 1200 numbers, we may by this method easily obtain the Napierian logarithm of any number with three places of decimals below 1·2.

*Copper Tests.*—The constants required for Copper Tests are those involved in correcting for temperature and specific conductivities. Another correction arises from the fact of the resistance coils themselves being adjusted at a temperature differing more or less from the temperature of the core or cable to be tested. As long as the resistances under consideration are small, these differences will be scarcely significant, but when these resistances are great it is desirable to eliminate these errors. Let us imagine a set of resistance coils correct at 65° F., which are found to be at 60° F., when testing coils at 49° F. or 75° F., differences of temperature which are by no means unusual, and it is at once apparent that this last correction will entail an additional labour of no small extent on the computer.

At the core factory, when testing at 75° F., we can easily obtain the correct values by a very simple method. A resistance coil of exactly 100 units at 75° F. is kept constantly at this temperature, and its value carefully compared with the resistance box previously to testing the core. Let us suppose that the 100 units adjusted on the box equal 99.2 units, then we shall have to multiply the measured resistances of the sections of core successively by $\frac{100}{99.2}$. If we set up on the face of the machine the reciprocal of .992, we may, by multiplying by the observed resistances, obtain the correct resistances, the extra labour being scarcely felt.

At the cable factory a table of constants for all the probable differences of temperature can be easily made, and considering the importance of knowing accurately the temperature of a cable, and the certainty of its determination from reliable copper tests, this extra expenditure of labour is amply compensated by the importance of its results.

When correcting the temperature to 75° F., if the temperature be lower than 75° F., the temperature co-efficient corresponding to the difference is put on the fixed plate, and the cable or core resistances become the multipliers. If the temperature be above 75° F., the reciprocal of the co-efficient is used.

To calculate tables of specific conductivities, we set on the fixed plate the resistance corresponding to the weight and temperature specified, and multiply by the reciprocals of the required per-centage values.

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SPECIFIC CONDUCTIVITIES

Corresponding to Resistances of a Conductor weighing 130 lbs. per Nautical Mile.

130 lbs. pure Copper=9·1722 B. A. Units per N. M. at 75° F.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 85 | 10.79 | 10.78 | 10.77 | 10.75 | 10.74 | 10.73 | 10.72 | 10.70 | 10.69 | 10.65 |
| 86 | 10.67 | 10.65 | 10.64 | 10.63 | 10.62 | 10.60 | 10.59 | 10.58 | 10.57 | 10.55 |
| 87 | 10.54 | 10.53 | 10.52 | 10.51 | 10.49 | 10.48 | 10.47 | 10.46 | 10.45 | 10.43 |
| 88 | 10.42 | 10.41 | 10.40 | 10.39 | 10.38 | 10.36 | 10.35 | 10.34 | 10.33 | 10.32 |
| 89 | 10.31 | 10.29 | 10.28 | 10.27 | 10.26 | 10.25 | 10.24 | 10.23 | 10.21 | 10.20 |
| 90 | 10.19 | 10.18 | 10.17 | 10.16 | 10.14 | 10.135 | 10.12 | 10.11 | 10.10 | 10.09 |
| 91 | 10.08 | 10.07 | 10.06 | 10.05 | 10.03 | 10.02 | 10.01 | 10.00 | 9.99 | 9.98 |
| 92 | 9.97 | 9.96 | 9.95 | 9.94 | 9.93 | 9.92 | 9.91 | 9.89 | 9.88 | 9.87 |
| 93 | 9.86 | 9.85 | 9.84 | 9.83 | 9.82 | 9.81 | 9.80 | 9.79 | 9.78 | 9.77 |
| 94 | 9.76 | 9.75 | 9.74 | 9.73 | 9.72 | 9.71 | 9.70 | 9.69 | 9.67 | 9.66 |
| 95 | 9.65 | 9.64 | 9.63 | 9.62 | 9.61 | 9.60 | 9.59 | 9.58 | 9.57 | 9.56 |
| 96 | 9.55 | 9.54 | 9.53 | 9.52 | 9.51 | 9.50 | 9.49 | 9.48 | 9.47 | 9.46 |
| 97 | 9.46 | 9.45 | 9.44 | 9.43 | 9.42 | 9.41 | 9.40 | 9.39 | 9.38 | 9.37 |
| 98 | 9.36 | 9.35 | 9.34 | 9.33 | 9.32 | 9.31 | 9.30 | 9.29 | 9.28 | 9.27 |
| 99 | 9.26 | 9.255 | 9.25 | 9.24 | 9.23 | 9.22 | 9.21 | 9.20 | 9.19 | 9.18 |
| 100 | 9.17 | | | | | | | | | |

*Calculations for Loss of Charge.*—We may write the formula, in terms of the per centage loss on C in this way:—$\left(\frac{1}{C} \times C\text{-}c\right) 100$, so that we have merely to multiply the reciprocal of the immediate discharge by the difference between this discharge, and that noted at the end of the time of insulating, usually one minute during which the cable or core is held free, the per centage value will be obtained by moving the decimal point two figures further to the right.

When C-c is a low number the result can be obtained by the simple inspection of a table of reciprocals, the multiplication being carried on mentally.

In this way I have drawn up a table for differences of 1 to 9 on all the Divisions of a Thomson's Galvanometer, so that all we have to do

is to look in the column "Charge" for the immediate discharge, and under the number corresponding to the difference will be found the per centage loss.

## TABLE,

For shewing rates of Loss for Static Charge, in percentage of the original charge for difference:—

| Charge. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 325 | 0.3077 | 0.6154 | 0.9231 | 1.2308 | 1.5385 | 1.8461 | 2.1538 | 2.4615 | 2.7692 | 3.0769 |
| 324 | 0.3086 | 0.6173 | 0.9259 | 1.2346 | 1.5432 | 1.8518 | 2.1605 | 2.4691 | 2.7778 | 3.0864 |
| 323 | 0.3096 | 0.6192 | 0.9288 | 1.2384 | 1.5480 | 1.8576 | 2.1672 | 2.4768 | 2.7864 | 3.0864 |
| 322 | 0.3106 | 0.6211 | 0.9317 | 1.2422 | 1.5528 | 1.8634 | 2.1789 | 2.4845 | 2.7950 | 3.1056 |
| 321 | 0.3115 | 0.6231 | 0.9346 | 1.2461 | 1.5577 | 1.8692 | 2.1807 | 2.4922 | 2.8038 | 3.1153 |
| 320 | 0.3125 | 0.6250 | 0.9375 | 1.2500 | 1.5625 | 1.8750 | 2.1875 | 2.5000 | 2.8125 | 3.1250 |
| 319 | 0.3135 | 0.6270 | 0.9404 | 1.2539 | 1.5674 | 1.8809 | 2.1944 | 2.5078 | 2.8213 | 3.1348 |
| 318 | 0.3145 | 0.6289 | 0.9434 | 1.2579 | 1.5724 | 1.8868 | 2.2013 | 2.5158 | 2.8302 | 3.1447 |
| 317 | 0.3155 | 0.6309 | 0.9464 | 1.2618 | 1,5773 | 1.8928 | 2.2082 | 2.5237 | 2.8391 | 3.1546 |
| 316 | 0.3165 | 0.6329 | 0.9494 | 1.2658 | 1.5823 | 1.8988 | 2.2152 | 2.5317 | 2.8481 | 3.1646 |
| 315 | 0.3175 | 0.6349 | 0.9524 | 1.2698 | 1.5873 | 1.9048 | 2.2222 | 2.5397 | 2.8571 | 3.1746 |
| 314 | 0.3185 | 0.6369 | 0.9554 | 1.2739 | 1.5924 | 1.9108 | 2.2293 | 2.5478 | 2.8662 | 3.1847 |
| 313 | 0.3195 | 0.6390 | 0.9585 | 1.2789 | 1.5975 | 1.9169 | 2.2364 | 2.5559 | 2.8754 | 3.1949 |
| 312 | 0.3205 | 0.6410 | 0.9615 | 1.2820 | 1.6026 | 1,9231 | 2.2436 | 2.5641 | 2.8846 | 3.2051 |
| 311 | 0.3215 | 0.6431 | 0.9646 | 1.2862 | 1.6077 | 1.9292 | 2.2508 | 2.5723 | 2.8982 | 3.2154 |
| 310 | 0.3226 | 0.6452 | 0.9677 | 1.2903 | 1.6129 | 1.9355 | 2.2581 | 2.5806 | 2.9032 | 3.2258 |

Tables for the per centage loss of Charge corresponding to different periods of time, and with different initial rates of loss, and similar tables calculated to shew the loss corresponding to different temperatures would be found very acceptable to the computer, and ensure an enormous saving of labour.

The former could be supplied by a table of the ratios for the values of $\log. \frac{C}{c}$, and from the same table, the initial per centage loss being given, we may readily construct another table for the time, in which any equimultiple of this loss shall take place.

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## TABLE OF COMMON AND NAPIERIAN LOGARITHMS,

For calculating Resistances from loss of Charge and for comparing Resistances, and for ascertaining the time required to fall to any multiple of its initial loss.

| Loss per Cent. | Ratio $\frac{C}{c}$ | Log. $\frac{C}{c}$ | Log. $e$ $\frac{C}{c}$ | Ratio of Logs. |
|---|---|---|---|---|
| 1 | 1.010 | .0043214 | .0099504 | |
| 2 | 1.0204 | .0087704 | .0198027 | 2.0295 |
| 3 | 1.031 | .0132587 | .0305293 | 3.0681 |
| 4 | 1.042 | .0178677 | .0411419 | 4.1347 |
| 5 | 1.053 | .0224284 | .0516433 | 5.1901 |
| 6 | 1.064 | .0269416 | .0620353 | 6.2345 |
| 7 | 1.075 | .0314085 | .0723207 | 7.2681 |
| 8 | 1.087 | .0362295 | .0834215 | 8.3837 |
| 9 | 1.099 | .0409977 | .0944007 | 9.4871 |
| 10 | 1.111 | .0457141 | .1052606 | 10.5785 |
| 11 | 1.124 | .0507668 | .1168937 | 11.7477 |
| 12 | 1.136 | .0553783 | .1275132 | 12.8149 |
| 13 | 1.149 | .0603200 | .1388919 | 13.9584 |
| 14 | 1.163 | .0655797 | .1510028 | 15.1756 |
| 15 | 1.176 | .0704073 | .1621188 | 16.2927 |
| 16 | 1.190 | .0755470 | .1739534 | 17.4821 |
| 17 | 1.205 | .0809870 | .1864795 | 18.7409 |
| 18 | 1.220 | .0863598 | .1988508 | 19.9842 |
| 19 | 1.235 | .0916670 | .2110711 | 21.2123 |
| 20 | 1.250 | .0969100 | .2231435 | 22.4256 |

The ratios of log. $\frac{C}{c}$ will also shew the relative resistances of Cores or Cables having different rates of loss for the same time.

Following upon this we can easily see that if we set on the face A A, the initial ratio of log. $\frac{C}{c}$ and multiply successively by the temperature co-efficients for correcting Dielectric resistances, we can rapidly compute tables for loss of Charge at different temperatures.

*Inductive Capacities.*—In calculating tests of Inductive Capacity, the Constant is set up on the face of the Machine, and multiplied by the discharges from the Coils of Core or Cable, when we obtain the absolute capacities.

When the sections are about the same length, or give discharges which can be read with the same shunt, the capacities can be worked out as rapidly as they can be taken off.

If different shunts be used with the Condenser and Core or Cable, it will of course be better to correct the Condenser Discharge to the same shunt as the Core or Cable discharges are noted with.

A table for correcting the values of the deflections on the scale of a Thomson's Galvanometer would be very serviceable, inasmuch as we should then be able to dispense with the present necessity of adjusting our shunts so as to obtain the Discharges on nearly the same point of the Scale, and, which is more imperative, the higher are the multiplying powers of the shunts.

The Inductive Capacities for Cores of different dimensions can be worked out by the machine, and with very little trouble we could obtain an extension of those valuable tables published by Mr. Latimer Clark and Mr. Sabine. The rate of variation being directly as the co-logarithm of $\frac{D}{d}$, or inversely as the log. $\frac{D}{d}$, we multiply the constant which is set on the machine in the first case by the complement of the log. $\frac{D}{d}$, and in the other case by the reciprocal of log. $\frac{D}{d}$.

*Dielectic Resistances.*—The constant $\phi \times \sigma \times n$ is set up on the fixed plate, and multiplied by the reciprocals of the deflections obtained on different sections of core, when we obtain the absolute resistances on the upper figure holes of the slide, the multiplier also appearing in the quotient holes.

In applying the corrections for temperature, the co-efficient should be set on the face AA; but when it is necessary to divide by the co-efficient, the reciprocal of this number should be set on, when we have only to multiply by the resistance for the results at the required temperature.

In computing tables for temperature corrections, and similar tables which consist in expanding a given number, the values which are made to appear on the slide must be transferred to the face for the next value, and so on; but if the logarithm of the given number be

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set on, every turn of the handle will give us the logarithm of a new term of the expansion. In this we can scarcely claim any advantage for the machine beyond ensuring accuracy in the results.

Tables of Electrification Ratios could be rapidly computed by putting on the face the deflection noted at the end of the first minute or period of contact, and multiplying by the reciprocals of the deflections at the end of the succeeding intervals. In these cases however, we must not forget the corrections necessary to be introduced, when the deflections and the galvanometer constant are on widely different parts of the scale.

In dealing so minutely with these numerical operations, my apology must be that the short cuts so familiar to us in calculating are extended to the machine, and that they are only developed by an acquaintance with its working, and in these respects I can add my humble endorsement to the statements of Major-General Hannyngton and Dr. Zillmer.

The machine requires peculiar methods, and in operating with it we have to present our formulæ in a condition suited to its ready performance. The constants in all cases must be determined from the law of variation indicated in each particular case.

In conclusion, I may remark that in every instance I have found it extremely useful, and in most cases of very great assistance. The object of my bringing this before you rests on the assurance that the first step to betaken in bringing electrical testing within the limits of exact science must be to reduce the mental drudgery of calculating, for we must admit that the time occupied in testing bears a small proportion to the time spent on working out the results.

Mr. W. A. Gilbee, of South Street, Finsbury (the agent for the Thomas de Colmar machines), kindly placed two of the machines before the meeting, which facilitated the comprehension of their action in the numerical operations referred to.

## DISCUSSION ON THE PAPER.

The President said, when he first heard of this paper he had some doubts, however interesting the Colmar machine might be, whether it was in itself suitable for this Society; but the more he had seen and heard about it, the more he was satisfied the subject was one of great interest to Telegraph Engineers; they had so much to do with calculations of an intricate kind, that he was quite sure the meeting

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would support him in proposing a vote of thanks to Mr. Warren, for his interesting paper. He would now call upon gentlemen to offer observations on the paper, and he would ask General Hannyngton, who had given a great deal of attention to this machine, to open the discussion.

General HANNYNGTON, F.S.S., F.I.A., said, it was not in his power to add to what Mr. Warren has done so well. He had shown many useful applications of the machine, and those applications were so numerous, that no one person would pretend to say he knew all about it. He (General Hannyngton) had used it himself for many years, but he still regarded himself as a learner. It might require some ingenuity to adapt the machine to the various purposes to which it could be applied, and he had no doubt of its value in electrical calculations. They all knew that even where calculations were not of an arduous nature, or such as to occasion any great strain upon the mind, after some hours' work the head would get weary, whereas this machine always remained perfectly cool.

Mr. HARBEN said the establishment with which he was connected had had six of these machines in operation for many years, and he supposed they had more of them in use than any other individuals. He should say they had made from half to three-quarters of a million of calculations by these machines over a number of years. In the first three months of their use they saved their cost three-fold in the amount of labour saved. Previous to their introduction into the office, the clerks employed in calculations were completely exhausted after a time. They heard of the machine being in use in the Registrar-General's Office at Somerset House, which led them to try it, and since then it had been in operation every day. He had known calculations which took 100 hands six months to work, which were now done by the machine, and they had never found it faulty in any respect.

With ordinary intelligence and ingenuity, there was no difficulty in manipulating the machine, and he felt quite sure it would be of incalculable value to Telegraph Engineers in the saving of time it effected, and leaving them more time to devote to other operations, instead of their brains being racked by intricate calculations. The practice in his establishment was to do the work with one machine and check it with another, so as to avoid the possibility of error. He hoped the result of this paper would be the more extensive use

of this machine. He merely gave his own experience, and he was certain if Telegraph Engineers used it, they would find it an invaluable benefit.

Dr. Royston Pigott, F.R.S., said he had the pleasure of using three of these machines for the last four years, and a friend of his had used them for seven years, and he informed him he had been able to make calculations during that time for five hours a day which would have taken at least twenty clerks to have accomplished. He would be sorry to say anything in disparagement of this machine, but he would impress upon beginners, the necessity of taking great care that they did not spoil them. He recollected, in his own early days with the machine, on one occasion he got it locked fast, and he had to take it to pieces before it would work again.

With regard to the elaborate paper they had heard this evening, there was one remark he would make as to the purposes to which this machine was applicable—that was the extraordinary power of the machine in changing its operation. If they multiplied a long sum by a given multiplier, they could by reversing the stop change the operation instantaneously without going through it again. He had found other uses of the machine in the employment of natural sines and tangents. He had one machine which would work up to twenty figures; and he found he could work by natural sines and tangents more rapidly than by logarithms.

Mr. Peter Gray, F.R.A.S., said he was unable to say a great deal about this machine from personal experience, but General Hannyngton lent him one of his machines for some weeks, and as far as his avocations permitted he had tried it in a great many operations. He might mention, as showing the impression it produced upon him, and his opinion of its capabilities, that when the Board under whom he was engaged were desirous of making an acknowledgment for some service he had rendered, and being allowed to decide the form it should take, he elected to have one of these machines, so that he hoped soon to have one of his own. It occurred to his mind that the machine was capable of a great many applications. It required some consideration perhaps as to the best way in which the formulæ could be put; but perhaps the most obvious way of proceeding was not always best for the machine, and he apprehended it was only scientific arithmeticians who could make the best use of the machine. To find out the various applications, and apply them in the best manner, required a scientific

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arithmetician. The advantage gained was not only rapidity of calculation, but the means of proving the accuracy, which was a very important thing.

Mr. RICHARDSON remarked, that something had been said about the machine getting out of order. With ordinary care, there is no greater liability to disarrangement of its parts than with any other machine of a similar kind. The only thing was, that with a considerable amount of usage, the parts most subject to damage, were the small springs, of which there were a great many, and which held the figure plates in their position. Of course it depends upon the number of times they had to be turned round, but they were so placed on the plate that they could be easily replaced if broken; and he believed the springs were supplied by the agent over here at a moderate price; and the machine was easily put to work again. He thought one source of damage was not always getting the moveable plate exactly in position before the machine was worked: and that gave a play which did not allow the teeth to come into the position they should. With ordinary care it was as little liable to get out of order as any other machine of the same kind and size. If they were made in England, he thought they would work with greater freedom. He believed they were all made in France, but some parts might be improved upon, if they were made in this country.

Colonel WALKER, Superintendent of the Grand Trigonometrical Survey of India, (responding to the President's invitation) said hitherto he had not used this machine, because in India he had such a large number of computors, who could be obtained at comparatively small wages, he had had no necessity to do so; but since he had been in England he had not had equal facilities in the shape of computers. He had borrowed one of General Hannyngton's machines, which saved him a great deal of labour and gave accurate results. He was thinking of employing it in India, where, notwithstanding they could get native computers who were very skilful, he thought it could be used with advantage.

THE PRESIDENT asked General Hannyngton if he had found the machine liable to get out of order?

General HANNYNGTON replied, not at all; on the contrary, the machine was very easily kept in order, and with ordinary care would not get out of order. The simplicity of the machine, considering its capabilities, was most remarkable. He might be a little of an enthu-

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siast about it, but he thought if it was introduced into the navy, ships might be navigated without much writing, which was of great importance in a gale of wind.

Colonel WALKER concurred in the observations of General Hannyngton, that the machine had great capabilities for working navigation, and, what was more important, it would give great accuracy.

Mr. WARREN said he had little to remark in reply. The principal point raised was as to the liability of the machine to get out of order. In the establishment with which he was connected they had one of these machines about the middle of last November, and at first he was not pleased with the results, but he was so fascinated with the idea of getting rid of laborious mental calculations, that he determined to persevere. With regard to the machine getting out of order, the only parts liable to do so were the springs: sometimes they get out of order. That depended upon the number of calculations they had to make. Of course a machine would not last in working order for an indefinite period; but the only parts he had found go wrong were the springs, which could be easily replaced.

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*The following Candidates were balloted for and duly elected:—*

AS MEMBERS:—

Matthew Gray, India Rubber, Gutta Percha and Telegraph Works Company.
J. C. Laws, Telegraph Construction and Maintenance Company.
Professor Williamson, London University.

AS ASSOCIATES:—

Edwin Ashton, Post Office Telegraphs, Camden Town.
Andrew Bell, Post Office Telegraph Stores, London.
E. Beckinsole, Telegraph Construction and Maintenance Company.
Alexander Bain.
Louis J. Crossley, Halifax, Yorkshire.
Charles E. Collings, Post Office Telegraphs, Plymouth.
Frank Carlisle, Post Office Telegraphs, Plymouth.
George Henry Comfort, Post Office Telegraphs, Nottingham.
Thomas Denmead, Post Office Telegraphs, Exeter.
George Field, Post Office Telegraphs, Brighton.
Henry Fischer, ditto Telegraph Street
John Grant, Secretary, Anglo-American Telegraph Company.
George Henley, Islington.
Henry Harborow, Marylebone.
A. W. Heaviside, Post Office Telegraphs, Newcastle.

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Frederick Hawkins, Silvertown.
John Jenkin, Post Office Telegraphs, Newark.
John Henry Knight, ditto Doncaster.
C. H. Kerry, ditto Bristol.
Robert London, Telegraph Construction and Maintenance Company.
John Neale, Telegraph Engineer, North Staffordshire Railway.
G. Noble Partridge, Post Office Telegraphs, Exeter.
Arthur Radcliffe, Birmingham.
E. T. Rolls, London and North Western Railway.
Hylton Spagnoletti, Marylebone.
Alexander Siemens, 3, Great George Street.
Albert Tubb, Post Office Telegraphs, Southampton.
William Grigg Taylor, Telegraph Contruction and Maintenance Company.

As Foreign Members:—
M. Breguet, Paris.
Hon. William Orton, New York.

The meeting then adjourned till the 24th April.

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The Meeting appointed to be held on Wednesday, the 24th April, was unavoidably postponed to Friday, the 26th April.

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The Fifth Ordinary General Meeting was held on April 26th, 1872, C. W. SIEMENS, Esq., F.R.S., President, in the Chair.

THE PRESIDENT announced that the Council proposes to alter Rule 25 of the Rules and Regulations, and requested the Members to consider that notice was given that the Ordinary Meeting on the 8th May, will be a Special General Meeting of the Society for that purpose. The contemplated alteration in Rule 25 consists in omitting the words "1st July," and substituting the "1st January."

The following paper was then read, "ON ARMY TELEGRAPHS,"

By CAPT. MALCOLM, R.E., Member of Council, S.T.E.

From the earliest ages down to the present time, telegraphy has been used in one form or another to co-operate with, and to assist in, the movements of Armies and Navies in actual Warfare, but the history of the early systems of Military Telegraphy has been so well and lucidly explained, and this part of my subject so exhausted, by Captain Colomb, R.N., in his paper "A Sketch of the Progress of Sea Telegraphy," that I feel it best to abandon the past and to lay before you, in as few words as possible, the condition of the Telegraph in the British Army at the present time. And looking upon telegraphy as the art of communicating intelligence with great rapidity, I include in my sketch what is known by us as "Visual Signalling;" a new service, the want of which was discovered and supplied by Major Frank Bolton and Captain Colomb, R.N.

It is, of course, evident that telegraphy is not taken up in the army as a commercial speculation, but with a strictly limited and defined view, viz:—that of communicating intelligence and orders as quickly as possible to and from the General or other Officer in command. In order that he may receive all sorts of intelligence speedily, it is evidently necessary that he should be "en rapport" with the main lines of the country in which he operating, if there be any; if not, as in Abyssinia, he must manage to

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bring a line along with him from his base of operations, so as to let the good people at home follow his operations from day to day at their ease.

This would be what we term a *semi-permanent* line, so that our telegraphic system divides itself into four classes.

The Permanent, of which the existing Postal Telegraph system may be taken as an example.

The Semi-permanent, or line connecting head-quarters with the nearest or best permanent line, which is considerably used in India.

The Field-telegraph proper, which connects head-quarters with at least the Divisional Generals, and does as much more as it can, its duties being however, mainly to connect the various portions of the army itself.

And the Visual Signalling system, by which the various Commanders are put "en rapport" with their own out-stations, posts, picquets, patrols, etc., and by means of which also, communication from shore to ship may readily be maintained.

Here in England, the country of compromises, we are unfortunately not able to act on any very coherent plan in order to discover our deficiencies, and remedy them in times of peace, the result of which not unfrequently is that systems are established which work thoroughly at home, but are not fitted for the roughness of war, and which have to be made to work at a fearful expenditure of men, money, and brains, in the critical moment; so that the military hail the system of autumn manœuvres with great satisfaction, as a means of guessing our deficiencies (for as yet the scale is too small for us to talk of really finding them out).

This which is true of the army generally—for the keenest, though *possibly* not the wisest of all criticism, and the most anxious desire for improvement is to be found within the army itself—is particularly the case with us who are, so to speak, charged with the supply of intelligence to the army, but we cannot at all times do what we would—it costs money.

I feel convinced that it would be most desirable that we should be allowed, and may I say compelled, to attempt the erection of a long semi-permanent line of telegraph, that the officers and men who will have some day to be working in the front, may gain some insight into the slightly different working of a line of this kind.

I believe that for the working, and probably for the erection and maintainance of this link between field and permanent lines, it is intended some day in some way, not yet arranged, that part of the permanent telegraphic officials and employés of the country are to be made available, and some of the officers and men of the Royal Engineers have been taken

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into the service of the Post Office that a few of the military may gain an insight into the working of their system; but looking to the tremendous development of the telegraphic system in the Prussian army round Paris, the Prussians, be it remembered, having with admirable foresight organized and made available the whole of the telegraphic resources of their country, I say, looking to this, I cannot consider that one, two, or three troops will be enough to maintain the telegraphic service in the event of our being engaged in a great war, after our generals have learned to use and trust the telegraph, and yet it has been abundantly proved by experience, that to work this sort of extra military service right up to the front, as we term it, amongst the turmoil, bustle, and danger of actual warfare, by other than military men accustomed to the forms, no less than to the hardships of military life, is very difficult.

There are so many little rights and wrongs in the army as in every other profession, so many exasperating little etiquettes, that the English civilian *pur et simple* finds hard to account, or indeed to allow for; then, again, the stranger has to get so much assistance from the soldier before he is able to perform his task, and is so liable to rub him up the wrong way by some small ignorance, and so not to get the assistance required by the one, and ready to be rendered by the other if only asked for in the so-called proper way; in short, there is so much human nature in man that I cannot but feel that if the military telegraphic service is to be a success in time of war, the whole of the arrangements ought to be well rehearsed in time of peace.

One critique on the volunteer review of Easter Monday (with which I cordially agree) is, that the skeleton at least of the Divisional and Brigade Staff should be *permanent*, that the Generals should know something of their Brigadiers, the Brigadiers their staff, and so on, before the day of the review. If this be advantageous among military men who are all of a trade, much more must it be desirable to unite military men in peaceful rehearsal, before they take part together in the bloody game of war.

Well, then, it is presumed that somehow a staff will be organized which will be competent to take care of the telegraphic communication along the permanent and semi-permanent lines, and this semi-permanent line will always be brought as near the head-quarters of the army as it conveniently can, and as far forward too as may be, leaving as short a link as possible between the out-posts of the army and itself to be filled by the Field Telegraph and Visual Signalling troops.

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For this service we have at present ONE troop of the Royal Engineer Train which consists of—

FIELD TELEGRAPH TROOP (21ST SEPT., 1871).

| DETAILS OF EQUIPMENT. | cwts. | qrs | lbs. |
|---|---|---|---|
| Weight of Wire Waggon (empty) | 15 | 2 | 14 |
| Do. do. (loaded) | 30 | 2 | 14 |
| Do. do. (carrying detacht.) | 43 | 1 | 7 |
| Do. of Drum of Wire (½ mile) | 1 | 1 | 16 |
| Do. of Office Waggon (empty) | 16 | 2 | 21 |
| Do. do. (loaded) | 21 | 1 | 21 |
| Do. (carrying Telegraphists) | 26 | 3 | 14 |
| Number of miles of Insulated Wire carried by Troop | 36 | | |
| Number of miles carried by each Waggon | 3 | | |

| ESTABLISHMENT. | | No. |
|---|---|---|
| Officers | | 4 |
| Non Commissioned Officers (mounted) | | 25 |
| Do. do. (dismounted) | | 16 |
| Artificers. | Shoeing Smiths | 7 |
| | Carpenters | 2 |
| | Wheelers | 4 |
| | Collar Makers | 3 |
| Trumpeters | | 3 |
| Sappers | | 93 |
| Drivers | | 72 |
| Signallers | | 20 |
| | Total | 249 |

NOTE.—The establishment of Telegraphists is not yet fixed. The duties have been performed by picked men from Sappers and Miners.

and is divided into three sections, each carrying twelve miles of the insulated wire, in half-mile lengths, which lengths are very conveniently and expeditiously joined together by an ebonite jointer, by which a practically water-tight joint is made in less than half-a-minute, which can, without detriment, be undone in even less time, to facilitate the search for faults.

Of course people will always be ready to cavil at anything and to say that other plans should be followed, even in the question of insulated *versus* naked wire and poles. I am not here to defend the system which has, after much thought and careful and exhaustive trial on a small scale, been accepted, but to tell you what the system at present is, and it gives me great satisfaction to be able to say that in a letter received after the Autumn Manœuvres last year from the Captain commanding the solitary telegraph troop, I was told that, except from the cuts inflicted upon the cable, probably out of curiosity, which in war time would be very summarily dealt with, the cable stood remarkably well, and proved, as far as he had means of judging, a perfect success. I have seen a cable recently manufactured which, if fresh line were wanted, I should be inclined to prefer; but I would not give up the present one without a very long course of trial.

The question of guarding the line, either in peace or war, is not yet definitely settled amongst us.

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The present pattern of cable is a strand of three, No. 20 B. W. G. copper wires, tinned, insulated with india-rubber, and protected by a layer of strong canvas, primed with india-rubber, and laid on with spiral twist, to ·3 of an inch diameter. Weight, 300 lbs. per mile.

This insulated wire is, as I said, divided into half-mile lengths, and carried upon wooden drums, which again are carried on "wire waggons," to be drawn by six horses.

These waggons consist of the under carriage and wheels of an ordinary general service waggon, the whole made as light as possible; upon this carriage are ranged drums, in two rows, so placed on framework that the wire may be paid out as required from the rear drums as the waggon advances. Thus on each wire waggon is carried three miles of wire, and also two dozen iron poles, intended to lift the wire overhead when passing cross roads; for although the cable is so strong and good that it has stood, and will successfully stand, a great deal of ill-treatment—such as carts and carriages passing over it, when laid unprotected on a hard Macadamised road, yet it is not to be expected that anything less durable than a rod of iron could stand the traffic of an army. The poles are formed of wrought iron tubing in two lengths, the butt 10 ft. long and 1¼ in. in diameter, the top 9ft. long and 1 in. in diameter, fitting inside the butt, and fastened when in use by a bayonet catch.

These poles can be stayed if necessary by three guys, which are provided.

The wire is held in a wooden plug, which fits into the top of the pole.

There is also carried by each wire-waggon a hand-barrow which is fitted with legs, and, as occasion demands, with wheels, so that it is able to take a drum of cable where the wire-waggon may either not be able or not be required to go. The weight of the hand-barrow is 25 lbs.; the spindle on which the drum revolves 7½ lbs. If a handle for reeling the wire up after being laid out be carried, then another 5 lbs. is added, and the weight of a drum complete with its half-mile of wire is all but 200 lbs.

To complete the furniture of the waggon we have two wrought iron earth-plates, 18 inches long, 4½ inches wide, and some ⅛ inch thick (which is strong enough to be driven home in any possible soil), and a six-gallon cask of water to ensure some moist earth.

This, with a jointed ladder of two 9 feet lengths, and some spikes to lift the wire on to a wall if wanted, closes the list as far as main items are concerned.

There is a very neat arrangement on the hind wheel, by means of which the wire, when laid out, can be rolled up. This is done with

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pulleys on the axle and on the drum axles, a strap passing over each, as soon as the waggon moves forward, the drum revolves and winds in the wire. The introduction of this arrangement, which is found to answer perfectly, has made a great saving of labour, and so much added to efficiency that, whereas the line can only be laid out about 3 miles an hour, it can be taken up at a rate of from 3½ to 4 miles per hour.

Finally, there is a little hooked stick for lifting the wire as delivered on to the hedges or fences which ordinarily bound roads.

The office waggon is not at all unlike a travelling photographer's van; its Length is ... ... 9ft. 5in.

| | | |
|---|---|---|
| Breadth | ... | 4ft. 6in. |
| Height | ... | 8ft. 6in. |
| Weight (empty) | ... | 16 cwt. 2 qrs. 21 lbs. |
| Internal space | ... | 5ft. 4in. × 4ft. 2in. × 5ft. 6in. |

And on service it will probably require four horses to draw it, as it carries the necessary stores and instruments to form a pretty complete Electric Telegraph station, together with a set of day and night visual signalling apparatus of the most approved form.

There are the following instruments in this office waggon:—A pair of Morse recording instruments fitted with Siemens' polarised relay, and with Digney's felt ink roller, which has been chosen as being so very portable, and always ready. A pair of these instruments are permanently attached to a table in the waggon and to batteries beneath.

Two more military inkwriters are carried spare, to be available for quasi-permanent offices, and two military sounders for small branch lines, when "recording" is either not necessary or practicable.

There are also spare batteries.

The lines are brought in and out to these instruments through holes in the side of the waggon, which I may tell you is made up of a substance highly approved in the army, viz., "Clarkson's material:" very thin wood strengthened in an extraordinary manner by the application of stout canvas by means of glue; of this material we build our office waggons, our pontoons and our tool boxes; in short, almost everything that requires great power of withstanding rough usage, with the utmost attainable lightness.

The pattern of battery at present in use is a form of Daniell arranged for portability by Quarter-master Serjeant Mathieson, R.E., of the Electrical School at Chatham; but I think our experiences lead us to rely more and more on the Leclanehé form, which perhaps may be adopted instead of the Daniell.

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The office waggon you may be sure is packed as full of stores and tools of all kinds as possible, and the utmost attention has been given to ensuring that by means of straps and cleats everything shall ride as securely as possible.

The waggon weighs when full and carrying telegraphers, 26cwt. 3qrs. 14lbs. allowing of course an average weight for the men.

It has been decided to carry the telegraphers, rather than make them either walk or ride, as they are thus relieved—1st. from bodily fatigue; 2nd. from the care of their horses at the end of the march, and are free to attend to their special work with the least possible useless expenditure of energy.

The office waggon is lighted by two small plate glass windows, and will shortly be supplied with roof lamps.

Opposite the telegraphers' table is a wicker pannier which makes a very good seat for the men, and contains a set of Visual Signalling Apparatus for day and night work, to enable communication to be maintained between the telegraph office, and the nearest signalling station, if visible.

In order to supply the troop and the rest of the Engineer Service with telegraphers, there is a School at Chatham, of which I am for the present in charge, which the men of the Royal Engineers are encouraged to volunteer for.

When a volunteer is accepted, after reference to his age, character, handwriting, &c., as likely to prove efficient as a telegrapher, he is received into the School for a probationary course of about three weeks, and his progress is closely watched. If he shews a want of aptitude he is at the end of this period recommended to return to his military duty; during this time he is instructed on the—

Single Needle } in reading and sending.

On "Morse," printing and reading.

He is taught the making up, and cleaning of Telegraph Batteries.

The tracing of the Single Needle Instrument.

To joint telegraph wires.

To erect telegraph poles and fix insulators.

At the end of three weeks he will be expected to have shewn aptitude for this speciality of work, to possess a thorough knowledge of the Morse "Alphabet," to be able to send at least 15 words on the "Single Needle" per minute, and to receive eight, and to have learnt well the other

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subjects, or he cannot be reported on as a man likely to become a valuable telegraphist, or to be passed into the second class.

SECOND CLASS.—The learner having passed his probationary course is advanced to this class, but continues to receive the instructional rate of working pay, that is less than he would earn at his regular trade

He will be instructed in:—

Morse printing { in reading and sending.

In reading by sound.

In testing cables (roughly).

In stretching telegraph line wire.

In firing mines and making up batteries.

The above will occupy 49 working days, at the end of which, those who have shewn special aptitude will be selected for advancement to the First Class, but those who have not been selected continue in the Second Class for a further period of 28 working days, to perfect themselves in their former instruction.

FIRST CLASS—As an encouragement and a stimulus to pursue this study with greater earnestness, as in a great measure the progress made will depend on the exertions of the individuals themselves, the Commandant recommends to the Secretary of State for War, that the non-commissioned officers and men selected for this class, shall receive their corps rates of working pay for the 28 working days, whilst being instructed in the following.

The higher testing of cables.

The higher branches of testing, such as for internal resistance of batteries, resistance of fuzes, &c., and instruction in Electro Magnetism.

CERTIFICATES—On the completion of the course, the learner is examined and his attained proficiency recorded on a certificate and issued to him.

The certificates are issued in the following manner:—

| Certificate. | Qualifications as Linesmen. | Classes which Learners must pass through. | RECORDER. To send in 5 minutes not less than (words). | SOUNDER. To receive and write not less than (5 minutes). | Remarks. |
|---|---|---|---|---|---|
| Very Superior | Good | 3rd, 2nd, 1st | 130 | 90 | |
| | Fair | 3rd, 2nd, 1st | 150 | 90 | |
| Superior | Good | 3rd 2nd | 110 | 75 | |
| | Fair | 3rd 2nd | 120 | 75 | |

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The wording of the certificates "Superior" and "Very Superior" must not be misunderstood, but rather taken with a grain or two of salt, for to tell the truth, the language is "strictly official," which, being interpreted, will mean worth 1s. 6d. a day, or 2s. a day working pay as a telegrapher; and the "testing of cables" also, does not apply to the management of what you know as cables, but to our cables in ½ mile lengths, which are tested for serious leaks and faults.

There are a good many who, with a handbook beside them, can do everything our means in cable will admit of, both with the Differential Galvanometer, and the Thomson's Reflecting Galvanometer, and are clever hands with the Resistance Coils. When I advised the Commandant of the School of Military Engineering to demand such speed of sending as that I have just mentioned, I confess I did it with some fear as to the result, but having by the kindness of Mr. Scudamore been allowed to range freely through the Post Office Schools, I felt sure I had not asked more than I should get if well supported, and owing I believe, to the introduction of a big clock shewing seconds, by which the young fellows are accustomed to time themselves, I have now a class which sends 30 words a minute, and means to reach 35; of course this is high, and I could not expect such speed to be continuously kept up.

We have lately introduced the plan of sending buglers, four at a time, to be trained simply as manipulators, for somehow, (I suppose the inducements are not sufficient) there has been a great dearth of grown up volunteers lately.

Besides telegraphing, our school teaches, as you will hear shortly from Major Stotherd, the exploding of mines, when the student is initiated into the mysteries of continuous and divided circuits; of Grove's, Walker's, and other Batteries; of Platinum wire and Abel's fuzes; of Magneto and Dynamo electric machines, and Von Ebner's exploders.

With one of these exploders the other day a Serjeant sent from Chatham, blew down in Dublin a chimney 160 feet high, with an expenditure of only 13 lbs. gun cotton, with such success that the highest possible compliment was paid, viz: that it was said that the operation was evidently a very simple one, and that the precautions which the Commandant of the School of Military Engineering had suggested, were *entirely unnecessary*.

Yesterday we blew into the air two Martello towers, Nos. 35 and 38, near Hastings, to compare 200 lbs. of gun cotton with four times its weight of gunpowder, the ignition being electrical.

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I think I have now run through the principal points of the electric telegraphic service of the army in the field; I may add that telegraphers are rather largely employed in various military offices, and at such places as Shoeburyness, and that it is always held to be an advantage for a good clerk to be a good telegrapher as well. Besides my school at Chatham, there are schools in London and Aldershot, and, for all I know, at other places, where manipulation is taught. Some men, also, have been taught at Cannon Street, and it is in contemplation to introduce the instruction into the Royal Hibernian School. Also they work at it both at Roorkee and Madras in India.

It is hardly necessary for me to explain *in extenso* the system of Visual Signalling, for this has been done so recently by Captain Colomb, R.N., in the paper he read upon the subject.

Caps, handkerchiefs, and walking-sticks, are not official, but they are freely used for communication, anything, in fact, by which a dot and dash can be shewn or indicated, is from time to time pressed into the service—thus, a pipe working inside a glass, a knife between spoon and fork held in the fingers, has more than once done service in a public house, but, officially, we make use of flags, shutters, fog horns and lamps, and I hope this year to see what can be done with the sun's rays.

For some years we at Chatham have been wanting to try it, but difficulties of all kinds have intervened; chiefly want of time between the successive classes coming up for instruction, and the smallness of the staff, whose time is almost entirely taken up in the interval that does come, in making the necessary repairs to the plant, &c.; but the subject has been brought before the Government by Mr. Mance, of the Indo-European Government Telegraph, and, as he has an instrument designed for the purpose, I dare say we shall be able to try what can be done with it; and it seems to me that if we can get the sun to work for us when he is shewing bright, and this lamp, in which you recognize a most portable form of Drummond light, to work by night, or when the sun is dull, we shall be able to do a good deal to extend the range of visual signalling. I may mention that I am not quite satisfied with the lime pencils, and that money has been taken up this year for experiments, either to improve them or to substitute a better material.

The lamp you see just burns spirit, and the almost pure hydrogen flame is intensified by the oxygen which is held in this bag, and is forced out by the pressure due to the weight placed upon it.

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The gas bag weighs hardly anything, and holds enough for *two* hours' hard work. I was much exercised to get a tap for the bag that I could consider entirely satisfactory; it must, of course, be tight, as light as possible, and offer as few points as possible to destroy the bag with when packed up or knocking about.

Captain Colomb explained the little code book, by means of which almost everything can be said by telegraphing a few numbers, according to the code he showed you. It has been proposed to add a column of letters beside that of figures, and so enable those who choose to telegraph by a code of not more than three letters instead of four figures, which letters, those who were accustomed to use Morse, would, I think, use with advantage. I think that when once they have learned it they will be sure to keep themselves in practice—that, at least, is the experience of Chatham; and if our views are correct the signalling parties will not have to depend absolutely on a code book, which may be lost. I hold that a code is very valuable, especially for fixed permanent stations; but that if we could make our army signallers thoroughly conversant with Morse as well, we should add greatly to the flexibility of the system.

I have gone thus at length into the question, chiefly on account of remarks that we made at the last meeting but one, to show the members of this Society that the services are not altogether asleep, and that we want to do our best according to our lights; and this reminds me that we deliberately prefer one white light, such as this before you, to mixtures of lights, as one is more simple, and because questions of colour blindness and of penetration do not enter into consideration.

It occurs to me to mention an accidental experiment I made last year in consequence of a remark made to me by Mr. Robert Sabine, viz: I attempted with one of these lights to illuminate the clouds of the sky, that is, I arranged one day that this should be attempted from 8 p.m. to 9 p.m. I then went home to dinner; after dinner I went out to a spot about two miles off, but in the mean time a dense fog had come up so that I could not see a fullsized windmill close to me. I thought there was no hope, but to my surprise I detected a pulsation in the fog, and watching soon told me that it was my lamp, and then I saw its light reflected from a wood at least a mile beyond me, and this glow was seen by two brother watchers over an angle of at least 12°. I shall be glad to get any information bearing upon this point.

It is doubtless within the knowledge of all, that before the introduction of the electric telegraph there was a semaphore system between

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London and Portsmouth which used to get a special message (sent at a stated hour each day) through in 31 seconds.

We have not yet come to such a pitch, but the practice last year at Chatham was to send parties for the last two days of their course long distances out towards Dover with a view of enclosing it, and we found one station which made me determine to introduce a light telegraph equipment.

A gently rounded table land fell with a steep declivity upon the fat weald of Kent, on the top of the cliff a signalman ensconced in bushes could see from Wye to the sea, and almost from Folkestone to to Beachey Head, but he could not signal to his own people more than a very few yards, so I had a cable made which only weighs 49 lbs. per mile, and a little battery which will work through two military "*Sounders*" as long as you please. Now our look-out can stay till his enemy is past him if he chooses telegraphing away to the Visual Signal Station at the back of the round top, whence a desirable station sends news 8 or 10 miles in a homeward direction.

It also often happens that a signal station which may be excellent to send on from may not be good to send back from a wood, the point of a hill or something may intervene, then this little telegraph line and battery steps in enabling the central station to be split in two with the least possible waste of time.

Let us now run back rapidly over the ground we have been so long upon.

We recognize in the *first* place, four great divisions, the permanent, the semi-permanent, the flying or field, and the visual telegraph.

The first is left entirely in civil hands, the second does not appear to be fully arranged, for as yet but only materials for 100 miles are in course of collection. As to the third, we have one troop organised with 36 miles of insulated wire; and the materials, waggons, &c.. but not men or horses, for two more troops are in course of collection. As to the fourth, there have been:—

## TELEGRAPH SCHOOL.

| | |
|---|---|
| Total number of men instructed since 1857 - - - - - | 350 |
| Telegraphists sent to Persia - - - - - - - | 28 |

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## SIGNALLING SCHOOL.

Since March, 1869—

| | | |
|---|---|---|
| Cavalry | Officers | 18 |
| | Men | 36 |
| Infantry | Officers | 150 |
| | Men | 286 |
| Officers of Indian Army | | 41 |
| | Total | 531 |

passed through the School at Chatham, the work done at this school is, I believe, thorough and good as far as it goes, but I daresay many will doubt whether it goes far enough, and whether any subject once taught can be retained without constant practice and supervision.

However, with subsequent practice or supervision, I have nothing to do beyond recommending the necessity to the attention of the powers that be.

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## DISCUSSION ON THE PAPER.

The President said they had heard a paper on a most interesting subject, and one which had been brought very usefully before them. Previous to inviting discussion, he would ask the meeting to pass a vote of thanks to Captain Malcolm for his communication.

The vote of thanks having been unanimously accorded,

Mr. W. H. Preece said: During the last Autumn Manœuvres, it was his special duty to make such arrangements between the Military department and the Postal Telegraph department so as to render the commercial system of the greatest possible benefit to the Military authorities; and while engaged upon this duty, he had the pleasure and benefit of inspecting and examining the system adopted by the Royal Engineers which had been so clearly described by Captain Malcolm. He saw the waggons and all the apparatus in full equipment and work, and he must say that anything more perfect he never witnessed. With the eye of a practical man he criticised carefully, and he was gratified to say that the faults he found were very few. The first thing which struck him was this—that in using, for the temporary and rapid purposes of military telegraphy, a system of this kind, it would be better to abandon the use of the recording instrument and depend entirely upon that of sound. Sound instruments are so much lighter, simpler, and more portable. They are

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so little liable to get out of order, and they bear rough usage with impunity. The ideas on Sound versus Visual Telegraphy were being very much revolutionised in England. They had hitherto always regarded the recorder as the proper thing, because it was assumed to be more accurate. He could not speak from actual experience of this fact, but from all the facts collected, and the opinions he had obtained, it appeared that the reverse was the case,—sound telegraphy was far more accurate than recording telegraphy. It was generally stated that the eye was more accurate than the ear, but he did not agree with this. The reason why he thought sound telegraphy was more accurate than visual telegraphy was excessively simple, viz., that the act of reading by the ear generates that accurate division of time so necessary in the Morse telegraph, so that a clerk who was able to read by ear would send more accurately than one who merely read by the eyes; hence errors were less numerous. This fact was brought to his notice on hearing the paper, when the author described the rate of sending and receiving at Chatham. His experience was that it was the greatest mistake to teach clerks rapid sending. Rapidity generated inaccurate sending, and incorrect sending generated errors. The result was, when they learnt men to send 30 words per minute, they were practically useless in the office, from the numerous errors they made, whereas those who read by sound were not only accurate, but they gradually acquired that rapidity which was wanted. Thirty words per minute was as much as could be expected from an experienced clerk, though, under pressure, they got 35 and 40; still, taking the average of all the work done, practical men seldom exceeded on the average more than 30 words per minute. He, therefore, thought that by endeavouring to get this high speed from the men at Chatham, the Royal Engineers were working in a wrong direction. He would sooner see a man, after three or four months' teaching, send 10 words accurately than 30 indifferently. It appeared to him that the wire used by the Royal Engineers was not the best adapted for the purpose. It was always easy to find fault, but difficult sometimes to find a remedy; and though he found fault with the wire, he was not prepared then to suggest a remedy. The waggons themselves were light and strong, and fully adapted for the purpose, so much so, that their advantage was so apparent in the field manœuvres, that the Postal Telegraph department had adopted arrangements very similar to them for use at race meetings, boat races, and emergencies of that kind, and they would, he had no doubt, be very largely employed.

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Major R. H. STOTHERD said: Captain Malcolm has so exhausted the subject, I have but little to say. There is one point, however, on which he has not touched, and that is, "the use of the Electric Telegraph to connect the several parts of a fortress:" this is a matter which must not be lost sight of. The mode in which this duty may best be performed, was very well exemplified during the recent siege of Paris by the Germans. Paris is what may be termed a first-class modern fortress, consisting of an *enceinte* surrounded by a series of detached forts: previous to the siege in question, each of these forts was connected to the *enceinte* and to its neighbours, by three separate means of telegraphic communication, namely, an air line of electric telegraph, carried in the usual manner on poles with insulators, an insulated line of electric telegraph buried several feet beneath the ground, and a line of visual signalling. I was informed by an officer of the Engineer corps, who had had charge of the electric telegraph during this siege, that the air lines were destroyed in a very few days by the shells of the besieging Germans, that the buried lines were efficient up to the very end, having been in such a position as to be protected from injury, and that in consequence of these latter lines remaining in good working order, the visual signals were scarcely required at all. The practical result obtained, carries with it a very plain lesson, namely, that an underground line, well buried beneath the surface, is the best for securing telegraphic communication between the *enceinte* and the detached forts of any modern fortress, and that for this purpose an air line is of very little value. During last September, I had the pleasure of attending the manœuvres of the Italian army, in the neighbourhood of Verona. Each corps d'armée had on this occasion, a Field Electric Telegraph Equipment attached to it. This equipment was constituted very much like our own Field Electric Telegraph, namely, with an insulated line to be laid on the ground, and travelling office waggons; their equipment was, however, supplemented by an air line, carried on poles, for certain special purposes, such, for example, as passing through the streets of a town. This equipment was used by the contending corps, during the manœuvres, in precisely the same manner in which it would have been used in actual warfare, and when laid out was most carefully patrolled night and day by a strong military guard, to insure its safety. In addition to this simple military guard, the men of the Telegraph corps were told off into watches, and stationed along the line, each watch relieving the other at intervals; in carrying out this latter system, each man was provided with the means of repairing an

insulated line of telegraph, and carried a small set of tools with him for this purpose; his duty was to walk along a certain section of the line at intervals, and examine it carefully. During these manœvures they had no difficulty whatever, such as we had last autumn, with their lines of telegraphic communication, simply because they were treated precisely as they would have been during actual warfare, and only those directly connected with the management of the telegraph lines were permitted to interfere with them. The line, which was insulated with gutta percha, was not in a very perfect state, the insulation being much cracked by the dry heat of the climate. This same telegraph equipment played a very important part during the war of 1866, and they seemed very well satisfied with its organization and mode of working. I had an opportunity of ascertaining what the French had done, in preparing a military Telegraph equipment, previous to the last war. In this respect they formed a strong contrast to the Germans. The latter had, long before the war, organized and improved, by all possible means, a very extensive system of telegraphic communication for field service. The French had a system of field electric telegraphy, but it was wanting in efficient organization and miserably deficient in material and men. They had at the beginning of the war only 5 officers and 150 men, exclusive of drivers, attached to their military field electric telegraph. These numbers were found utterly insufficient for the extensive operations undertaken, and it became necessary to supplement them by the addition of 60 or 80 employés from the civil telegraphic service of the State, under a civil chief. Even with this addition they could not perform the work required satisfactorily, and the men and materials were captured very early in the campaign, in consequence of the rapid advance of the German armies In speaking of the French field telegraph equipment to a Prussian Officer of the Guards Pioneer Battalion, at Berlin, he mentioned the French field telegraph batteries as having been very efficient. I did not see these batteries, but from the description given, I am inclined to think they were of the Leclanché form, a pattern greatly in favour with French telegraphists, by whom they are very extensively used. On the advance of the German armies to Paris, a telegraph corps, consisting of 2 officers and 144 men, the latter consisting of 50 Gardes Mobiles, who understood the working of telegraph instruments, 44 employés from the civil telegraphic service of the State, and 50 messengers was organized under a Captain of the Engineer corps. These were all placed under military

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discipline, the mixture of the civil and military elements in the original organization not having been found to work satisfactorily. With this corps the telegraph lines, connecting the several detached forts round Paris, were manned and worked very effectively. The visual signalling apparatus, arranged as an alternative method of communication, was manned by a body of seamen from the fleet: in consequence of the very complete nature of the electrical system, it was not called much into requisition. With reference to a remark of Mr. Preece, in the selection of a Morse recording instrument for military, telegraphic purposes, I beg to say that accuracy in the transmission of military orders, during a campaign, is of the most vital importance; hence the necessity for a recording instrument, as by this means a printed record of each message, as well as the name of the sender and receiver, may be retained, and should a mistake occur its author may be easily detected. It is no doubt for this reason, coupled with its portable form, that the Morse recording instrument has been adopted, for military telegraphic purposes, by the French, the Germans, the Italians, the Austrians, and I believe also by the Swiss. The advantages and disadvantages of an insulated, as compared with an air line, for military telegraphic purposes has been frequently discussed. It has been decided to use an insulated line for our service, because our equipment is so very small in men and materials, that we could not attempt to carry out such a scheme as that employed by the Germans. For the long lines of communication, in which the Germans employed their air line of Field Electric Telegraph, we should employ, what may be termed, a semi-permanent line, of uninsulated wire carried on poles, keeping the insulated line as far as possible for operations in the front. An insulated line may be very much more quickly laid or removed than an air line, and has been proved to be perfectly efficient for the actual operations of war, during the Italian campaign of 1866.

Capt. Mallock said that Military Telegraphing in India had hitherto always been performed by civilians attached to the army; and generally speaking the work had been carried on with light wire carried on bamboo poles. It had been done thus in several campaigns, such as in the Mutiny, and in the Sitana Black Mountain and Bhootan Campaigns; and quite recently in the Looshai Expedition. It had, however, been some 3 or 4 years since determined by the Government to establish an entirely military establishment for telegraphy, because civilian signallers under military authority were not always found to answer well. This plan, proposed by Colonel Robinson, and partly sanctioned by Government,

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was to transfer one of the civil divisions of the department about a thousand miles to a military company with officers, that is, a Captain and some subalterns, having, for signalling, European soldiers on the unattached list (a term hardly understood in England, but they are soldiers holding staff appointments) whilst Native sappers would do the out-door work of the lines. It was intended, supposing it were necessary, to send a detachment of this branch of the service, with a field force, to send the whole establishment from one sub-division of, say, 250 miles, and their places would then be temporarily occupied by civilians, moving up a detachment of both signallers and Native line men. So much for the men. The next thing was the *material*. This comprised instruments and materials for semi-permanent and temporary lines, similar to what they saw this evening. With regard to the instruments, they had come to the conclusion of using the recording instruments. What they wanted was a recorder that was not only light and portable, but one which would do anything required. The lightest thing they could get made in this way, was about 25 lbs. weight; but it would not do everything required, whilst an instrument which was thoroughly serviceable was only from 35 to 40 lbs. weight. Now, when they considered that they only wanted one instrument for about every 10 or 15 miles of line, the extra 10 lb. weight of the instrument, or a pound a mile, was of little consequence. He had placed on the table for the inspection of members, an instrument with which they could do anything wanted. The semi-permanent lines, it must be remembered, were not always independent lines; they were, generally speaking, merely derivations from the main line circuits. They were not taken into main stations but strung on to the middle of the main line wires, and, therefore, had to be worked by a split current. This necessitated a good instrument at the end of the line, as it would generally have to do as much work as the instruments on the main line. It would be noticed that the arrangement of the connections was novel, and was so designed that by putting another instrument opposite to this, the translation connections could be made at once by joining the terminals, which were opposite each other. A smaller instrument, for field use was now under consideration, but it was not yet made. After the instrument came the lines. This (holding up a specimen) was a small insulator calculated for wire, of No. 12 gauge, which could be fixed on to trees or on the sides of rocks, &c. This description of insulator might be considered heavy for military and portable purposes, but the conclusion they had arrived at was that

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they might just as well have no insulator at all as a makeshift one, and where no great insulation was required a bamboo pole alone was as good a thing as they could have. For ground lines, there was a material here (pointing to an insulated wire) which would bear four times more strain than that now in use by the Royal Engineers, and this was got by making it more as a cable, that is rather as a cable with the strength inside. They did not want great conductivity, so that instead of a strain of six copper wires surrounding one there was but one copper with six iron wires round it, and no damp could get in; there would be no local action, and this extra strength to either, with the covering upon it, ought to be sufficient to prevent what was the chief trouble of these military lines, viz: pack cattle treading upon and breaking them. To revert to the commencement of the subject, the chief reason why they wished to get soldiers as signallers on the permanent establishment of the department was that they had come to the conclusion that men learning in the school and then going back to their regiments were only amateurs, they learnt and they forgot, and it had, therefore, been now proposed to the Government that these men should be kept at the work constantly, so that what they learnt should be fixed in their minds, and they would always be ready when required for duty on active service. A great deal of what he had said was not what they had done but what they proposed to do. With regard to the necessity of patroling alluded to by Major Stotherd during the Delhi siege, the way the patroling was done was by native horsemen, both irregular cavalry soldiers and line men of the department, being sent along the route of the line at night time. They stole along quietly, feeling the line with their spears. When they no longer felt the wire they had necessarily an idea it was broken, and the ends being found it was mended at once. During the Bhootan campaign every inch of the line was inspected every morning between 6 and 9 o'clock. Where the wire was suspended on bamboo poles, these were continually being knocked over by the pack cattle. There was generally an interruption from this cause every day, but in most instances the wire was put in order again by 9 o'clock in the morning.

Mr. Von Chauvin stated the results of his experience of military telegraphs as carried out in the Prussian armies during the late war. He stated it was clearly shewn in the campaign of 1866 that modern warfare was almost an impossibility without the aid of the electric telegraph in the field. In peace time a large staff was kept in training to be ready for duty in time of emergency, the operators being taken from the

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Government telegraph establishments. Soon after the commencement of the campaign with France there were 300 telegraphers ready to start with the advanced portion of the army, and communication was at once established between the van and the rear of the army. The Telegraph corps were furnished with the Morse recording instrument, and they did not employ sound signals at all. The party accompanying the advanced army carried very light poles and thin copper wires, using also insulated wires for ground lines, or fastened in such a manner as circumstances rendered necessary for the temporary service required. The Morse instruments were of about the same weight as those used by the Government telegraphs. A second party put overland wires on poles of a medium size, and by that means communications were made with regard to stores and supplies for the armies, which had all to be sent from home. A third portion of telegraphers followed the rear of the army as it advanced in the French territory, changing the temporary lines of the second party into lines of the size and durability of the usual Government lines. The greatest use of the telegraph was experienced in the cases of sieges of towns and fortresses. It would have been impossible to have kept on the siege of Metz and Paris, without the electric telegraph. A circuit was kept up round Paris of 20 German miles, and it would readily be seen that it would have been impossible to have filled up that enormous space with men. Two sets of overland wires were put up out of reach of the French bullets, each line consisting of four wires, establishing communications with 24 different stations, and thousands of messages were sent round Paris every day. The Emperor of Germany expressed his opinion to Moltke, that it would have been impossible to have made the siege of Paris without the telegraph, or to have maintained the siege of Metz so long. The second advantage of the telegraph was with reference to the supplies of food and materials for the army by means of communication by the overland lines. All supplies of food for that immense army had to be sent from their own country, as no adequate supply was to be found in the districts of France which they occupied. By the telegraph arrangements, however, when supplies were demanded, messages were sent on stating at what time the food, &c., would arrive. A further advantage was experienced in regard to the conveyance home of the sick and wounded. It was often the case that the lines were overcrowded with trains, carrying men, guns, ammunition, &c It was due to the electric telegraph that the wounded and sick reached the hospitals, where they were properly treated, much sooner than they otherwise would

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have done; and after the system had been brought into regular working order, the telegraph was opened as much as possible for the private messages of the officers and men of the army. That could not be done of course till they had established a great many stations, nor till communication was effected with the chief stations. Whenever possible, one wire was appropriated to private messages at stated charges, payment for which was generally made at the place to which the messages were sent. The point mentioned by Capt. Malcolm as to securing the safety of the line in an enemy's country was a very important one. This was done in the last campaign by means of patrols. It was rare that a line could be kept in order for 24 hours, and the work of repairs was very considerable. The only means of security was to make the French authorities interested parties in the good working order of the lines, any interference with the telegraph wires being punished by a heavy requisition upon the town; this system was found to work better than anything else.

In reply to a question by Capt. Malcolm, Mr. Von Chauvin stated he did not know how many miles of line they had, but they found a very large stock of telegraphic material in France.

Captain Colomb, R.N., said, one branch of the subject touched upon by Captain Malcolm was the visual signalling carried on in the army where the electric telegraph was not possible. It was always to be understood that when practicable the electric telegraph was the best, but sometimes it could not be employed, and then they must have recourse to visual signalling. We should be glad to hear whether visual signalling was carried out in the Prussian army, and if so what system was employed. It was not generally known, but it was said that the defeat of the main attack by the Communists from Paris upon the troops at Versailles was accomplished by visual signalling from Mount Valerien. From that fortress the movements of the Communist troops could be watched, and the communications made by signal enabled the commander of the Versailles army to be in the right place at the right moment. In the Red River expedition the movements of the troops were mainly conducted by visual signalling, and thus connection was kept up between the transport by land and by water, and in such a case visual signalling was the only means that could possibly be employed. He should like to hear Captain Malcolm's opinion upon the introduction of visual signalling into the permanent military stations at home, chiefly for the purpose of practising those who would be called upon to use visual signalling in war; also to what extent permanent stations were so used at present, or

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if any were so employed? Captain Malcolm spoke of using the sun's rays as an auxiliary means of communication by visual signals. In the year 1858 he (Captain Colomb) carried out a great many experiments of that nature with an instrument invented by Mr. Francis Galton, and the great difficulty he met with was from the motion of the earth. When the range was of considerable length the motion of the earth interfered with the signalling in a very few seconds of time, that was when they had the ray directed to the person they were signalling to, one or two seconds of the motion of the earth were sufficient to take the ray off his eye, and that made accurate communication almost impossible. At short distances, where the earth's motion did not interfere so much, they got accurate signalling. There was a simple arrangement which he thought might be utilized, employing not the sun's rays but the sun's light. The suggestion came from the late Professor Babbage, who pointed out that in any given day when the sun did not shine, the brightest object was the zenith, and if they reflected a portion of the zenith to the station they wished to communicate with, they would probably send a signal further than they could by any other means. He had not carried out complete experiments in that way, but those he had tried confirmed Mr. Babbage's view, and he thought by the adoption of a reflecting shutter apparatus it would be possible to get a range of visual signalling by day greater than in any other way. The shutters should lie at an angle of 45°, making the surfaces reflecting either by looking-glass, or better still, by polished nickel, which did not tarnish and was almost everlasting when once polished. Even with the opaque shutter apparatus, Major Bolton and himself had sent signals a distance of 15 miles with great rapidity, which it would have been impossible to have done with any other description of visual signalling. In working from the shore to a ship at sea, he had no doubt, with an apparatus of this kind, they could transmit messages a distance of 30 miles. With reference to the lights employed for signalling, it was important that they should be really serviceable. He was a little in doubt whether the Royal Engineers were wise in adopting the oxy-calcium or lime light, after the experience Major Bolton and himself had had of it. Knowing, as they did, that good light as it was when things were in order, it was most unsafe to rely upon it when things were not in order. It was impossible, thoroughly, to rely upon the lime light. The Chatham light which he exhibited when he read his paper on Sea Telegraphy, was devised by Major Bolton and himself in consequence of the inconvenience

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they found in the use of the lime light. He rather regretted that the Royal Engineers having that light in an imperfect form in their own hands did not put it into some more perfect form, inasmuch as he thought something better than the present arrangement was required, and the Chatham light presented, at least, the germ of all which was necessary.

Captain WEBBER, R.E., said he was much impressed in connection with this subject with the great importance of having a system of military telegraph of the most perfect kind, if used at all as a means of communication for an army in the field. They knew so great was the importance that a Commander attached to the entirety of a message being delivered at a distance that he would frequently send his messages from one place to another by six or seven persons going different routes; and a Commander was known in one instance to send a message by sixteen different means, so great was the importance of the delivery of that message. Therefore if a General was at a distance from the place on which he depended for his supplies or his reserves, the means of communication by telegraph must be of the most perfect and reliable kind: in addition to that he must have alternative lines or means of sending messages; therefore it was better to have no line of telegraph at all than have an unsatisfactory one, and that being the case he felt anything that was likely to add to the efficiency of the system was of the greatest importance. He hoped the system would be so perfected as to prevent the possibility of the recurrence of that disaster which once occurred to the British army through a mistake in the delivery of a message in the time of battle.

Mr. LATIMER CLARK said he would make a small contribution to the history of this subject. He was glad to hear that the Authorities were now alive to the employment of telegraphy for military purposes; but if he was correct, our Government was not among the first to take up the matter. The first introduction of it in this country, he believed was due to Mr. Ricardo, a former chairman of the Electric Telegraph Company, who in 1853 or 1854, proposed a system of military telegraph which was not then adopted, but which bore a great resemblance to that described to-night. Mr. Ricardo proposed to employ two waggons, one carrying men and tools and the other coils of gutta percha covered wire wound upon drums, in a similar way to that which they had seen: also handbarrows for smaller quantities of wire, and a system of joining the wires similar to that shown on the table. He also proposed to use coils of naked wires which could be run out by hand with small pulley-shaped

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insulators and bamboo canes. The instrument was a single needle instrument supported on a common level tripod, and a battery was suspended between the tripod legs.

This system was described at the time in a pamphlet, and a set of apparatus was constructed and exhibited, and he mentioned it to show that in those early days the plan had been brought before the Government. Another point of interest was that Mr. Ricardo proposed to make use of a kind of knife-edged plough which, after cutting a furrow, deposited the wire in the earth as it went along, the plough being worked by horses, four or five miles of wire per hour could be laid along the sides of an ordinary road. When a hard piece of ground was encountered, the trench was opened by the men in attendance. Wires so laid were not, of course, liable to the injuries which open air wires were likely to receive, and he thought the subject still worthy of the attention of Capt. Malcolm and the Military Authorities.

Mr. H. C. Donovan mentioned that during the American war military telegraphists carried with them small instruments with wires attached. Those wires were connected with the existing main lines of telegraph, and the lines were tapped in that way. He believed many important secrets were discovered in that way by the northern army. He agreed with Mr. Preece in his preference for signals by sound instead of by the recording apparatus; inasmuch as sound left no trace behind from which mischief might arise.

Capt. Malcolm R.E. (in reply), said he confessed when the duty of preparing this paper was put upon him, he was much afraid of it, but the discussion had been so full of instruction that he was glad that he had undertaken the task. On the question with regard to the recording instrument, he would say though it left its tale behind, it was an easy matter to destroy it if necessary for purposes of secrecy; at the same time, they must not forget the immense importance to Commanders as well as the public of conveying the exact message sent. They had not yet forgotten Balaclava, and what resulted from the message delivered there. It was the subject of remark at the time, that if the message had been written it could have been appealed to afterwards. With regard to Capt. Mallock's telegraphic system, he thought it was unnecessary to enter into a discussion as to the merits of that system over what he (Capt. Malcolm) had described. He believed it was used with very good results in the line at Varna. He was extremely gratified by the enconium Mr. Preece had passed upon the work of his (Capt. Malcolm's) predecessors.

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He appeared before them as having carried out what they with a great deal of labor had prepared. As to rapidity of signalling, he did not think Mr. Preece quite understood his observations. He did not want his men to go into competition with those who were in the habit of signalling fast, for their time of instruction was not more than about six months; but he thought when they were able to drive the machine at a pretty good rate, they were less likely soon to forget what they had been taught. With reference to the French Communists having been routed by means of visual signalling, he (Capt. Malcolm) did not know whether that was the case or whether the telegraph was employed, as his information pointed to the use of the telegraph. He would like to hear from M. Von Chauvin, how many miles of wire the Prussian army had in use on the occasions referred to; because although he believed we had started in the right direction, our lines at present did not exceed 36 miles in length. He apprehended the Prussians must have had some hundreds of miles.

Mr. Von Chauvin said he did not know how many miles of line they had, but they had a very large stock of wire he knew.

The President said all would agree that they had listened to a most interesting paper, and one of great public interest. If there was one thing clear, it was that the electric telegraph was one of the most important weapons that could be employed against an army; and it was surprising to him that our Government should have limited itself in the use of that weapon. He hoped this paper and discussion would serve to convince them of the great importance of this subject in military warfare.

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*The following Candidates were then ballotted for and duly elected:—*

As Members:—

Charles Hockin, Avenue Road, St. John's Wood.

Lieut-Colonel Sprot, 93rd Highlanders.

As Associates:—

George Blewett, Postal Telegraphs, Oxford.

John Charles Chambers, Postal Telegraphs, Stockton-on-Tees.

John H. Cordeaux, Postal Telegraphs, Birmingham.

Thomas H. Crampton, C.E., London.

John Doherty, Postal Telegraphs, Manchester.

J. R. Edwards, Postal Telegraphs, Chester.

Frederick E. Evans, Postal Telegraphs, Birmingham.

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William Lloyd, Whitehall Club.
G. James Morrison, Clifton Extension Railway, Bristol.
Martin Noble, Postal Telegraphs, Lancaster.
J. Possmann, Indo-European Government Telegraphs, Persian Gulf.
John Richard Preece, Indo-European Government Telegraphs, Ispahan.
John Brewer Saunders, Taunton.
John Shaw, Postal Telegraphs, Bolton.
J. H. Smith, 2, Westminster Chambers.
Julian H. Tolmé, C.E., Victoria Street, Westminster.
John Walton, Postal Telegraphs, Cardiff.
Lieut. Watkins, R.E., Chatham.
E. H. Werdermann, Princes Street, Southwark.
H. Schutz Wilson, Regent Street, London.
Lieut. C. Watson, R.E., Chatham.

As STUDENT:—
Edward Palliser, 2, Westminster Chambers.

The meeting then adjourned.

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The Fifth Ordinary General Meeting was held on May 8th, 1872, C. W. Siemens, Esq., President, in the Chair.

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The President announced that the Council thought it desirable that in Rule 25, the words, "1st July," should be omitted, and the "1st January" be inserted in their place; on the motion being put before the Meeting, it was carried unanimously.

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The first Paper read was On a Modified form of "Wheatstone's Bridge," and Methods of Measuring Small Resistances, by G. C. Foster, F.R.S., Professor of Physics in University College, London.

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The object of this paper is to describe simple methods for the following purposes connected with the measurement of electrical resistances, namely:—

I. The measurement of small resistances, by ascertaining what length of a graduated standard wire has an equal resistance;

II. The electrical 'calibration' of wires, or the division of them into lengths of equal resistance;

III. The elimination of errors due to the resistance of connections from determinations of specific resistance.

It will be seen from what follows, that the arrangement of apparatus employed for these purposes might be varied in many ways, but it will probably conduce to clearness if I confine my description to the arrangement that I have actually used. In all the experiments, the principal piece of apparatus, besides a battery and a galvanometer, was a Differential Resistance Measurer,—or, as it is commonly called, a "Wheatstone's Bridge,"—of the form usually made by Messrs. Elliott Bros., for purposes of demonstration and research; and, as I shall have to make frequent reference to this instrument, it may be well to give a brief description of it before speaking of the special purposes to which it has been applied.

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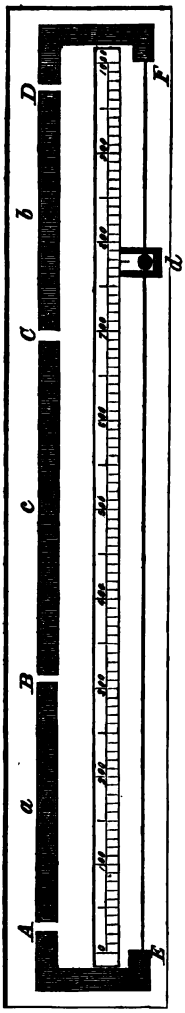
Figure 1 shews the arrangement of its essential parts on a scale of about $\frac{1}{7}$. A piece of german-silver wire, E F, from 1·5 mm. to 2 mm. in diameter and 1 metre long, is stretched upon an oblong board forming the base of the instrument, parallel to a metre-scale divided throughout its whole length into millimetres, and is so placed that its two ends are approximately opposite to the divisions 0 and 1,000 respectively of the scale. The ends of the wire are soldered to a broad copper band, which passes round each end of the graduated scale and runs parallel to it on the opposite side from the wire. This band is interrupted by four gaps, A, B, C and D, at each side of each of which is a binding screw for connecting the conductors whose resistance is to be measured. In the ordinary use of the apparatus, the wires from the battery are attached to the screws *a* and *b* fixed upon the copper strips A B and C D respectively, and the galvanometer wires are connected, one to the screw *c* on the strip B C, and the other to the screw *d* upon a moveable block, which slides along the graduated scale and allows contact to be made at any part of the german-silver wire, while an index-mark shows the distance of the point of contact from each end of the scale. The conductors to be compared are inserted at the two middle gaps B and C, and if they are of small resistance the end gaps A and D are usually closed by thick copper latches, or, if the resistances at B and C are considerable, conductors, whose resistances are known in terms of that of the wire E F, are inserted at A and D; it is easy to see that the effect of these, which may be regarded as ungraduated prolongations of the german-silver wire, is to increase the delicacy but to limit the range of the instrument. When the moveable contact *d* has been so placed that, on completing the battery-circuit, the galvanometer shows no deflection, it follows from the general principle on which the measurement is founded that—

FIG. 1.




resistance *a* to *c*: resistance *c* to *b* = resistance *a* to *d*: resistance *d* to *b*.

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In most cases we may substitute for this, as a fair approximation,—resistance at B : resistance at C = resistance E to $d$ + resistance at A : resistance $d$ to F + resistance at D, or

$$= \text{scale reading} + \left\{\begin{matrix}\text{length of wire equal}\\ \text{in resistance to A}\end{matrix}\right\} : 1{,}000 - \text{scale reading} + \left\{\begin{matrix}\text{length of wire}\\ \text{equal in}\\ \text{resistance to D}\end{matrix}\right\};$$

but in adopting this last value as representing the ratio of the resistances at B and C, we are exposed to sources of error which need not be pointed out to any one accustomed to electrical measurements, and which become of greater importance in proportion as the resistances to be compared are smaller. These errors are almost entirely avoided in the process now to be described.

I.—*Method of measuring small resistances by comparison with a graduated standard wire.*

The resistance of any wire, whose resistance is less than that of the whole length of graduated german-silver wire, E F, may be found in terms of the latter as follows:—Insert the wire to be measured at the gap A, close the gap D by a conductor of insensible resistance, and insert at B and C any two convenient conductors the ratio of whose resistances (which it is not necessary to know) does not differ from unity more than does that of the resistance to be measured and the resistance of the whole wire E F; then shift the moveable contact $d$ until the galvanometer ceases to be deflected, and take the reading of the scale. Next put the wire to be measured at D and close the gap A by a conductor without sensible resistance; shift $d$ until the galvanometer is again balanced, and take a second reading of the scale: *the difference of the two scale-readings gives the length of the wire* E F *whose resistance is equal to that of the wire to be measured.*

This result is almost self-evident, but it may be proved, if needful, thus:—Let L denote the total resistance of the wire E F, A and D, the resistances inserted at the two end gaps, $e$ and $f$ the resistances of the copper bands between $a$ and E and between $b$ and F respectively, and let B and C stand for the total resistances between $a$ and $c$, and between $c$ and $b$ respectively; also let $m$ be the scale-reading when the resistances A and D are in their first positions, and $m'$ the reading when they have been interchanged; lastly, let $k$ be the resistance of unit length (1 millim.) of the wire E F. Then the two experiments give—

$$\frac{B}{C} = \frac{A + e + mk}{L - mk + D + f} \text{ and } \frac{B}{C} = \frac{D + e + m'k}{L - m'k + A + f},$$

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whence, by equating the two values of $\frac{B}{C}$ and adding unity to each side of the equation, we get:—

$$\frac{A + D + L + e + f}{L - mk + D + f} = \frac{A + D + L + e + f}{L - m'k + A + f},$$

or

$$A - D = (m' - m)k.$$

In the measurement described above, we assumed the condition $D = 0$; if $m_o$ and $m'_o$ be the scale-readings corresponding to this condition, we have—

$$A = (m'_o - m_o)\, k.$$

But, since in practice the resistance D can never be reduced absolutely to nothing, it is important, when great accuracy is required, that its value should be known: a method is given further on (p. 203, 204) by which any resistance great enough to affect sensibly the reading of the instrument can be measured.

In order that measurements made in the manner that has been described may have a definite meaning, it is of course necessary that the value of the coefficient $k$, or the resistance of unit length of the wire E F should be known with reference to some recognised standard; and when, as in the instrument I have chiefly used, the resistance of the whole wire E F is a comparatively small fraction (about $\frac{1}{7}$) of a unit, some special method is needed for measuring $k$.

I have employed two methods for this purpose: the one which is, on the whole, the most convenient being the following. A wire whose resistance, R, is only a little less than that of the whole wire, E F, is measured in terms of the latter by the process given above: let $p$ be the number of millimetres between the two readings of the positions of the sliding contact, then

$$kp = R \ldots\ldots (1)$$

Next a standard (unit) coil of resistance S is combined in multiple arc with the wire already measured, and the measurement is repeated: this gives, if $q$ be the number of millimetres between the two readings in this case,—

$$kq = \frac{RS}{R + S} \ldots\ldots (2)$$

Whence we get, as the value of the coefficient required,

$$k = S\frac{p - q}{pq}.$$

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Another method is to insert a standard coil at one of the gap ends (say at A), and at the other (D) a wire whose resistance $R_1$ falls short of that of the standard by not quite the whole resistance of E F, and to shift the moveable contact until the galvanometer is balanced; then to interchange the standard and the resistance $R_1$ and shift the contact again till the balance is restored: let $d$ be the difference (in millimetres) between the two readings of the scale in this experiment. Next take a second wire whose resistance, $R_2$, falls short of that of $R_1$ by nearly the whole resistance of E F, and proceed with this and the first wire in the same way as with the first wire and the standard, and let $d_1$ be the difference between the two readings of the scale in this case. Proceed in this manner with wires of smaller and smaller resistance until one is arrived at of smaller resistance than the wire E F. Let the resistance of this wire be $R_n$: by inserting it at one of the end gaps and an insensible resistance at the other, and afterwards interchanging, we find by taking the difference, $d_n$, of the scale-readings in the two positions required to balance the galvanometer, the number of millimetres of the graduated wire whose resistance is equal to $R_n$. By a set of such experiments we obtain—

$$\begin{aligned} d\,k &= S - R_1, \\ d_1 k &= R_1 - R_2, \\ &\vdots \qquad\quad \vdots \\ d_{n-1} k &= R_{n-1} - R_n, \\ d_n k &= R_n; \end{aligned}$$

or

$$k = S \frac{1}{d + d_1 + \ldots + d_{n-1} + d_n}.$$

II.—*Method of testing the resistance of the various portions of a conducting wire, and dividing it into parts of equal resistance.*

It has been tacitly assumed in the foregoing that the coefficient $k$, or the resistance of 1mm. of the graduated wire E F, is constant from end to end. This, of course, is never strictly the case, and hence it is desirable to measure not only the mean value of this coefficient for the whole wire, but also its value for the different parts, or else to assure ourselves that the variations of value are too small to be of importance. This examination of the wire is very readily made by the arrangement represented in Fig. 2, which shews a second graduated wire E′ F′ connected with a "Bridge" of the form already described. So far as the same reference-

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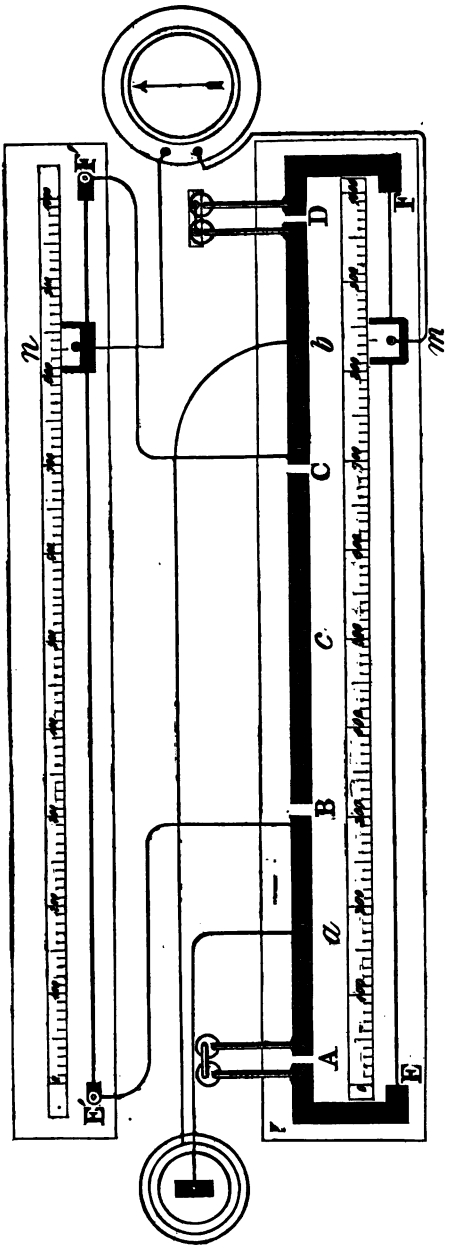
FIG. 2.

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letters occur in this figure and in Fig. 1, they mark identical parts: the battery is connected (through a make-and-break key not shewn in the diagram) with the binding-screws *a* and *b*, and the terminals of the galvanometer are connected with *two* moveable contact-makers, one of them *m* on the principal wire E F, and the other *n* on the wire E′ F′—for convenience of reference this will be afterwards called the "compensating wire" or "compensator"—the ends of which are connected with the outer binding-screws of the gaps B and C. The end gaps A and B are closed, the one by a short and very thick piece of copper wire of almost insensible resistance, and the other by a short piece of german-silver wire of resistance equal to that of whatever length of the graduated wire it is desired to test at once. This piece of wire serves the purpose of a gauge with which each part of the wire E F is compared in succession: in most of my experiments its resistance was equal to that of about 70 mm. of the wire to be tested. The gauge being (say) at the right-hand gap D (as in the diagram) the sliding contact *m* is placed at or very near to the right-hand end of E F, and the slider *n* is moved on the compensating wire so as to destroy the deflection of the galvanometer. The gauge and the thick copper connector are next interchanged, and the balance is restored by moving the slider *m*: as already pointed out (p. 198) the length of E F over which the slider is moved, is that of which the resistance is equal to the difference between the resistances of the gauge and the thick connector. The gauge and connector are now put back into their first positions, and the slider *n* is shifted until the galvanometer is again balanced; then they are interchanged once more and the balance obtained by shifting the slider upon E F. This process of successively interchanging the gauge and connector, and adjusting the galvanometer to zero, by moving alternately the sliders *m* and *n*, is continued until the former has been brought step by step to the further extremity of the wire E F. It will be seen that each shift of the sliding contact *m* is over a portion of the wire E F whose resistance is equal to the constant difference between the resistances of the guage and connector, and therefore that, by the process that has been described, the graduated wire is divided into parts of equal resistance, in a manner exactly comparable to that in which a thermometer-tube is "calibrated," or divided into portions of equal capacity, by marking on it the lengths successively occupied by a small quantity of mercury which is pushed along it.

The shift of the slider *n* also takes place over portions of the wire E′ F′ which have all an equal resistance, but this bears the same ratio to

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the resistance represented by the shifts of the slider $m$ that the resistance of the branch $a$ B E′ F′ C $b$ bears to the resistance of the branch $a$ A E F D $b$. To prove this, let the sliders be so placed that the galvanometer is in equilibrium when the gauge is at the gap D, and the gap A is closed by the thick connector: let the resistance of the gauge be denoted by G, that of the connector by C, the resistances of the wires E F and E′ F′ by L and L′ respectively, those of the permanent connections between $a$ and E and between $a$ and E′ by $e$ and $e'$, the permanent resistances between $b$ and F and between $b$ and F′ by $f$ and $f'$, and lastly the resistances of E $m$ and E′ $n$ by $r$ and $r'$, We then have the equation—

$$\frac{C + e + r}{G + f + L - r} = \frac{e' + r}{f' + L' - r'} \quad \ldots\ldots \quad (1)$$

Then, by interchanging the gauge and connector, and balancing the galvanometer again by moving the slider $n$ nearer to F′, while the slider $m$ remains where it was, we get the equation—

$$\frac{G + e + r}{C + f + L - r} = \frac{e' + r'_1}{f' + L' - r'_1} \quad \ldots\ldots \quad (2)$$

where $r'_1$ is the resistance between E′ and the new position of $n$, and therefore $r'_1 - r'$ is the resistance of that portion of the compensating wire over which the slider has been moved. By adding unity to each side of each of the equations (1) and (2), inverting the two new expressions thus obtained, and subtracting one from the other, we get—

$$\frac{r' - r'}{e' + f' + L'} = \frac{G - C}{G + C + e + f + L}$$

or

$$r_1' - r' = (G - C)\frac{e' + f' + L'}{G + C + e + f + L}; \quad \ldots\ldots \quad (3)$$

which shews that, with the same apparatus, at each shift of the moveable contact along the compensating wire, it passes over a constant resistance of the magnitude stated above.

The value of the multiplier of G—C in equation (3) is easily found experimentally; for, since the resistance passed over at each shift of the slider on the principal wire, E F, is equal to the difference G—C, denoting this resistance by $r_1 - r$, we obtain—

$$\frac{e' + f' + L'}{G + C + e + f + L} = \frac{r'_1 - r'}{r_1 - r} = M.$$

By help of this value, which for shortness may be denoted by M, exceedingly small resistances, such as that of the short copper connector mentioned above, are readily measured when they are connected so as to form part of the principal circuit. For this purpose, it is sometimes

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needful (in order that every measurement may come within the range of the instrument), to transfer the battery-wires from the binding-screws *a* and *b* to E′ and F′; when that is done, the factor M must be determined in this state of the apparatus, since the resistances *e′* and *f′* now belong to the principal branch of the circuit, instead of to the compensator branch. The galvanometer wire is now disconnected from the slider *m* and applied to one end of the connector (or other conductor whose resistance is to be measured), and the balance is got by means of the slider *n*; the galvanometer wire is next applied to the other end of the connector, and the balance is again got by the slider. Then if Q be the resistance over which the slider is moved, the resistance of the connector is given by—

$$C = \frac{Q}{M}.$$

As an example of the resistances which are easily measurable in this manner, it may be mentioned that in two experiments the resistance of a thick and short piece of copper wire was found to be equal to that of 0·6 millimetre of the german-silver wire E F, or to be about 0·00008 of a B. A.-unit.

When the graduated wire of the bridge has been divided as above described into sections of equal resistance, it is of course easy to make a table showing what fraction the resistance of any given part of it is of the total resistance. The manner of doing this is too obvious to need further description For the sake of comparison, a table was made by the above process for a bridge-wire which had become very irregular through rough usage, and a similar table was made for the same wire from the results obtained in comparing together by means of it, in the usual way, a set of coils of known resistances.* The numbers obtained

* The following was the method of calculating the resistance of each part of the wire from the experimental numbers :—

Let L denote the total resistance between the battery-connections through the bridge-wire, that is to say, the resistance of the branch *a* A E F D *b* (Fig. 1).
" R the resistance inserted at the left-hand centre gap B.
" *r* " " right-hand " C.
" *x* the (unknown) resistance between the zero-end (left-hand end) of the bridge wire, and the nearest battery contact, that is, the resistance from E through A to *a*.
" *a* the scale-reading for given values of B and *r*; and
" *k* the mean resistance of 1 mm. of the bridge-wire between zero and the point *a*.

Further let the values of the above symbols corresponding to the smallest value given to the ratio R : *r* be distinguished as $R_o$, $r_o$, $a_o$, $k_o$, and those corresponding to the greatest value of this ratio be distinguished as $R_n$, $r_n$, $a_n$, $k_n$.

Then any two experiments in which intermediate values are given to the ratio R : *r* give the two equations—

$$\frac{R_p}{r_p} = \frac{a_p k_p + x}{L - a_p k_p - x} \quad \text{and} \quad \frac{R_q}{r_q} = \frac{a_q k_q + x}{L - a_q k_q - x};$$

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by the two processes were almost identical; but I consider, nevertheless, that the method of the compensating wire and gauge possesses some advantages, since it does not depend upon the accuracy with which a set of resistance-coils have been previously adjusted, and the numerical calculations required are so simple that there is little danger of arithmetical error.

### III.—*Method of avoiding errors due to the resistance of connections in determinations of specific resistance.*

A method for this purpose has been described by Sir William Thomson (*Proc. Roc. Soc.*, [1861] vol. xi., p. 313), but probably a simpler and equally accurate process is to connect the wire to be used for the determination, in the place of the german-silver wire E F of a bridge of the form shewn in figure 1, and to proceed precisely in the manner already indicated at page 199, for the measurement of the resistance of the unit length of the bridge-wire. The result is in this case wholly independent of any resistance outside the extreme positions of the sliding contact-maker, and since this is only used for finding a point which gives *no current* through the galvanometer, the result is also unaffected by any moderate variation of resistance at the moveable contact itself. I do not think there could be any great difficulty in arranging the apparatus so as to admit of the wire between E and F being immersed in a bath of liquid, so that its temperature might be known with greater accuracy than is possible when it is exposed to the air, but I have made no attempts in this direction.

It will be seen that the accuracy of the methods of measurement

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whence we get, for the resistance of the wire between the points $a_p$ and $a_q$,—

$$a_q\, k_q - a_p\, k_p = \mathrm{L}\frac{\mathrm{R_q}\, r_p - \mathrm{R_p}\, r_q}{(\mathrm{R_p} + r_p)\,(\mathrm{R_q} + r_q)} \quad \ldots\ldots \quad (a)$$

Similarly, for the resistance of the whole wire, or more accurately for the portion of it between the extreme readings $a_o$ and $a_n$, we have—

$$a_n\, k_n - a_o\, k_o = \mathrm{L}\frac{\mathrm{R_n}\, r_o - \mathrm{R_o}\, r_n}{(\mathrm{R_o} + r_o)\,(\mathrm{R_n} + r_n)} \quad \ldots\ldots \quad (b)$$

The left hand side of this equation may also be written $(a_n - a_o)\, k'$, where $k'$ stands for the average resistance of 1 mm. for the whole length of the wire, a quantity which can be measured in the manner already mentioned (p. 199—200); hence the elimination of L from equation ($a$) by means of equation ($b$) gives—

$$a_q\, k_q - a_p\, k_p = (a_n - a_o)\, k' \frac{(\mathrm{R_o} + r_o)\,(\mathrm{R_n} + r_n)}{\mathrm{R_n}\, r_o - \mathrm{R_o}\, r_n} \cdot \frac{\mathrm{R_q}\, r_p - \mathrm{R_p}\, r_q}{(\mathrm{R_p} + r_p)\,(\mathrm{R_q} + r_q)}$$

It will be noted that only the last factor of this expression varies from one experiment to another of any one set, and hence the remainder can be calculated once for all.

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described in this paper, depends essentially on the possibility of connecting the conductors inserted at the two gaps A and D with the rest of the apparatus in such a way, that they can be taken out and put back again time after time, without causing any perceptible change in the resistance of the connections. In this respect, I have found the use of well-amalgamated copper rods, resting by their flat ends on an amalgamated plate of copper, forming the bottom of a mercury-cup of the form devised (I believe) by the late Dr. Matthiessen, and described by him and Mr. Hockin (*Rep. Brit. Assoc.*, 1864, p. 354), quite satisfactory.

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## DISCUSSION ON THE PAPER.

THE PRESIDENT having called upon members to ask any questions, or offer observations on the paper,

Mr. LATIMER CLARK said he was sure they had all listened with pleasure and advantage to the paper just read. To his own mind it seemed to add one more proof of the great value of the system of measuring by the Wheatstone Bridge, which was so indispensable to electricians. It might surprise some to hear that the instrument Prof. Foster had spoken of was not the invention of Wheatstone; yet it was in fact, invented by Mr. S. Hunter Christie, who read a paper upon it before the Royal Society in 1833, ten years before Prof. Wheatstone brought it a second time before the notice of the public. Mr. Christie was attached to the Royal Military Academy at Woolwich, and was the author of many papers on electricity in the *Philosophical Transactions*, and, among others, of an article on this subject which was dated 28th February, 1833, and in which he described what he termed his "differential arrangement," and the manner in which the instrument was applied to the measuring of the relative conduction of different metals. Among other things he compared the resistance of a length of 350 inches of No. 16 gauge wire, with a length of No. 22 gauge, which required 90 inches to balance it. Mr. Christie also employed it as a means of discovering the conducting powers of metals at different temperatures, and his arrangements were so sensitive that it was observed that the warmth of the hand causes the needle to vary sensibly. It was deduced, from a number of experiments, that the conducting power of metals varied as the square of the diameter, a fact which was not so well known then as now. Notwithstanding all the endeavours that were made at the time

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to make the invention known, it remained in oblivion till Sir Charles Wheatstone brought it forward again in the year 1843, when he wrote his remarkable paper on electrical measurement, in which he stated the source from which this invention was derived, and gave the dates of the papers which Christie had written on the subject. It was, therefore, not from any fault of Sir Charles Wheatstone that his name became attached to the instrument, although it was only fair to say that Christie did all in his power to make it known, and to point out its advantages. It was often the case that a man might be too soon as well as too late: in those days telegraphy was almost unknown: but in 1843, when Wheatstone called attention to the instrument, telegraphy had commanded great attention. Moreover, he had not long before carried out his brilliant experiments on the measurement of the velocity of light, which were so well known, and from that cause, combined with the admirable character of the paper in which the instrument was re-described, it had been since known as the Wheatstone Bridge.

Mr. S. Phillips, Junr., asked whether, in measuring small resistances, the functions which the resistance of the galvanometer might have upon them, had been investigated? He would like to be informed what was the resistance of the galvanometer, and what would be the most suitable resistance in order to get the greatest sensibility.

Professor Foster replied that he had not specially investigated that point. What he had actually used was a resistance of about 1 unit in the galvanometer. This matter was fully gone into, but he did not remember the results, some years ago by Mr. Schwendler in the *Philosophical Magazine*, which he thought was the best authority to refer to on the subject.

The President remarked that the resistance of the galvanometer should be nearly equal to the resistance to be measured, and the maximum of magnetic momentum was got, with arms of the balance of equal resistance.

Mr. Latimer Clark described by means of a diagram on the board, the form in which the instrument was used, as given in Mr. Christie's paper. He added, he should have reminded the meeting how much they were indebted to Dr. Werner Siemens for the great improvements he had effected in the instrument with respect to the unequal proportions of measurement, it had added tenfold to the value of the bridge.

The President said, having been connected more or less with the Wheatstone Bridge in its early application to telegraphic measurement, he would say that the instrument was first attempted to be used in

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testing coils of insulated line-wire by his brother in 1847-48. It was soon found that the range of the instrument was insufficient, and it occurred to his brother to construct these resistance-boxes so as to make the two arms of the balance variable, which gave a much larger range of reading. Instead of simply adjusting one weight with another on equal arms of the balance he made so to speak, the length of the arms variable, and got thereby much wider limits within which the instrument could be applied. Moreover, by the adoption of resistance-boxes a great deal of the difficulty which Professor Foster had met with was avoided: because the stopper made a very safe contact. Moreover the wire with sliding contact was apt to wear if much used, and the resistances of comparison consisted of fractions of units only, whereas the resistance to be measured amounted usually to hundreds, thousands, hundreds of thousands, and millions; it also followed from this condition that a galvanometer of exceedingly small resistance must be used, in order to get a proper proportion between those resistances, to give a maximum effect; whereas with box-resistances they could use a galvanometer of many thousand units in its point of maximum sensitiveness. He would ask Professor Foster to be good enough to state whether he had compared his improved instrument—which appeared to be very ingenious, as a method of avoiding errors in dealing with small resistances—whether he had compared that with the instrument with the resistance boxes?

Professor Foster replied that his mode of comparing resistances was one which would usually be adopted only where the resistances to be compared were very small, and for that purpose he suggested it. If they had to measure the resistance of two or three feet of moderately thick copper wire, then the resistance which was introduced even at the best made stoppers was a thing which could not be neglected. In measuring high resistances it was easy to make this resistance unimportant, but in dealing with small amounts it was not so easy; and for that reason he had not compared measurements made in the way that he had described with those obtained by means of resistance coils. One method was applicable to low resistances, and the other to cases of high resistance. Another difficulty with the resistance coils was they could only go by one unit at a time; though by using an unequal arm balance they could subdivide by hundreds and thousands, but then the measurement became less accurate. They introduced great resistance on one side and small on the other.

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The second paper read was on "Electrical Ignition of Explosives," by Major Stotherd, R.E.

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The application of electricity to the ignition of explosives has been productive of enormous advantages, whether applied to operations on shore or under water. Greater safety and certainty are attained in carrying on such work, especially as regards operations undertaken for the removal of wrecks or other obstructions to navigation, which are necessarily carried on under water. Many a fatal accident has occurred when a train or fuze has hung fire, which would never have taken place had electricity been the igniting agent; by it, operations are much simplified, and advantages are obtained, in the power to test the condition of our fuzes, when actually in position in the mine, and to tell with almost absolute certainty whether the explosion will take place when required. This is of incalculable value, especially if our mine be situated below the surface of the water. To electrical ignition, we may also trace the rapid advance which has lately been made in the science of defence by Torpedoes, or as they should be more properly called Submarine Mines.

It would be impossible, in the limits to which a paper of this nature must be confined, to enter exhaustively into the discussion of the several modes in which ignition may be effected on shore as well as under water; I propose, therefore, to confine myself chiefly to the latter, or subaqueous, portion of the subject, and especially to that part of it which relates to the fuze, believing that it will be more interesting, and perhaps novel, to those who have honoured me by their presence this evening.

The late General Sir Charles (then Colonel) Pasley, of the Royal Engineers, whose active mind was never idle, undertook the task of investigating the art of firing charges under water as far back as the year 1812. At that time but little was known as to submarine blasting; under his superintendence, however, a series of experiments was made, and the results obtained, as summed up by Lieutenant Jekyll, R.E., in a paper read by him at the Royal United Service Institution, are as follows: "He came to the conclusion that Bickford's fuze might be effectively used at small depths, but that it became uncertain at depths of 10 or 12 fathoms,

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for which and greater depths Sir Charles Pasley recommended a small linen hose filled with powder, enclosed in a leaden tube; the upper end of this tube was supported, at the surface of the water, by means of buoys. The diameter of this hose was one-tenth inch, and that of the leaden pipe 1 inch, and it burnt uniformly at the rate of about 10 feet per minute: the smoke issuing from the pipe gave an indication as to whether the hose was burning properly." Having advanced so far, he undertook the destruction of several wrecks, including that of the Royal George, sunk at Spithead, and, while engaged in these operations, introduced a system of electrical ignition, which though not so perfect as that which we at present use, numerous failures having occurred with it, did good service, even in this early stage of its development. He used the ordinary platinum wire fuze, fired by battery power, which was probably the first electric fuze used in connection with submarine operations of this nature. The firing battery used is said to have been a form of Daniell's, and the conductor a copper wire, one-eighth inch in diameter, insulated.

Daniell's Battery is, as you know, ill adapted to perform the work of fusing a fine platinum wire. Bunsen's, Grove's and other forms may be employed for this purpose with infinitely better effect. A form of Grove's battery was, after numerous experiments, made by Colonel (then Captain) Ward of the Royal Engineers, adopted for military land mining service about the year 1854. Grove's battery, though excellent in many respects, possesses one very serious defect, namely want of constancy: after remaining mounted for a comparatively short time, even when not actively at work, it loses power and it requires to be dismounted and cleaned and the porous cells to be well soaked in water, to clean out the sulphate of zinc which is deposited therein and fills up the pores: the battery, to be efficient for firing purposes, must be cleaned and remounted at least every 12 hours.

The difficulties in connection with the platinum wire fuze, which exist not in the fuze itself but in the battery required to fire it, occasioned the investigation of the question of an electrical fuse to be fired in some other way, and the numerous advantages to be derived from the use of a constant battery of high tension, or of the charge produced by an ordinary frictional machine, or by induced currents derived from an arrangement of permanent magnets, such as that of Sir Charles Wheatstone, or from the apparatus devised by Dr. Werner Siemens, and known as the "Dynamo-Electrical Machine," has given us what is

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termed the tension electric fuze. One of the first fuzes of this nature was that known as Statham's, discovered about the year 1840. This fuse was produced by passing an electric current through a bridge of sulphide of copper, introduced into a minute opening between the points of a pair of insulated conducting wires, which might be placed in the circuit of a voltaic battery. The passage of the electric current decomposed this subsulphide of copper, and produced sufficient heat to fire a priming Charge of gunpowder. Statham's fuze is said to have been discovered by accident—a slight break or rather want of continuity had occurred, in a piece of ordinary gutta-percha covered wire, due to the action of the sulphur, which was formerly used in the preparation of the gutta-percha, on the copper conducting wire; this had produced a decomposition of the latter, leaving a minute break in the conductor filled, however, with sulphide of copper, and it was noticed that on the passage of an electric current, through the comparatively bad conductor thus introduced into the break, great heat was produced, by which powder could be fired. This illustrates the general principle on which all fuses to be fired by a current of electricity of high tension are constructed, namely, a minute break in the wire conductor, into which a chemical compound, or mixture of compounds, is introduced in such a way that the current must pass through it, and produce heat sufficient to fire a priming charge in contact with it.

One of the most perfect fuzes of this nature is that devised in 1858 by Professor F. Abel, F.R.S., Chemist to the War Department. The original mixture, introduced between the wire terminals in this fuze, consisted of 10 parts of sub-phosphide of copper, prepared by a special method, 45 parts of sub-sulphide of copper, and 15 parts of chlorate of potassa; these proportions are, however, now varied so as to furnish fuzes of different degrees of conductivity and sensitiveness, to suit different purposes. The ingredients are reduced to a very fine state of division, and are thoroughly incorporated in a mortar, with the addition of a little alcohol. The mixture is then dried at a low temperature, and preserved in tightly stoppered bottles till required for use. This composition is extremely sensitive as an electric priming material, and is perfectly stable so long as it is preserved from access of moisture. This condition, essential to the permanent efficiency of the fuze, is secured in its present form of construction, and the precautions adopted in packing such warlike stores as friction tubes, time fuzes, &c., suffice to ensure the preservation of these fuzes.

In applying the electric spark to the explosion of fuzes, the distance

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from each other of the metallic points, between which the spark passes, must be adjusted with great nicety; it is also important, when a number of charges are to be exploded in divided circuit, by means of a constant battery or magneto-electrical machine, that no residue should be left between the poles, after the explosion of the fuzes, which would still serve to conduct the spark across the interval. The composition discovered by Mr. Abel completely fulfils the latter condition, and the former is ingeniously secured in the construction of the fuse, by means of an arrangement of double-covered, insulated wire, by which the distance between the wire points is very uniformly established.

Another fuze of this nature, more recently devised, is that of Baron Von Ebner, General in the Austrian Corps of Engineers. The priming in this fuze consists of a mixture of equal parts of sulphuret of antimony and chlorate of potassa:—a small quantity of powdered plumbago was formerly introduced into the composition, with a view of giving a certain amount of conductivity for testing purposes, it was however found to act prejudicially, occasionally giving too much conducting power, and rendering the ignition of the fuze somewhat uncertain, it has consequently been discontinued.

Another form of fuze, adapted for a current of high tension is that devised by Mr. Beardslee of New York. In this fuze the bridge is formed by means of plumbago, together with a small quantity of a substance, which importantly assists the plumbago in its action, the nature of which has, however, not been disclosed. This fuze, though adapted for a current of high tension, partakes more of the nature of the platinum wire fuze, having a metallic bridge which is, so to speak, burnt by the action of the electric current passing through it.

Abel's fuze is more extensively used than any other in this country for mining purposes. In its most sensitive form it is extremely delicate and certain in its action, considerable caution and skill is, however, necessary in testing it. The original form of fuze was much more easily tested with safety, but the extremely sensitive nature of the newer forms, though adding to their efficiency for the simple purpose of exploding a mine, renders the process of testing a very much more difficult operation. This is of comparatively little consequence in land mining operations, but where it is required for work under water, and especially in carrying out a system of defence by submarine mines, it becomes a more serious consideration. The reason of this is, that when submarine mines are put out for defensive purposes, they must frequently remain submerged for

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many months before they may be required to act, and if not effective exactly at the right moment, they would be perfectly useless. An instance of this sort occurred during one of the bombardments of Charleston, when the United States iron-clad, "New Ironsides," lay for several hours exactly over a very large submarine mine. Several attempts were made to fire this mine, all, however, without result. The reason of this failure was due to the severance of the electric cable by the passage of a wagon over it. The art of testing was not so well known then as it is now, otherwise the defective state of affairs would have been discovered. Though in this instance the defect lay in the cable, it is easily understood, under such circumstances, how necessary it is that we should have a fuze, as well as a cable, for work of this nature, which may be safely and effectively tested. The very delicacy and sensitiveness of Abel's mining electric fuze renders it a somewhat difficult and, without extreme skill and care, even a dangerous operation to test it, after being placed in position in a mine, as there is a certain chance of involuntarily exploding the charge while passing a test current through it. Under these circumstances, Mr. Abel undertook to devise another form of fuze for submarine mining purposes, and his labours have met with perfect success. His new fuze, called the "Submarine Electric Fuze," is constructed somewhat as follows:—

The bridge consists of a very intimate mixture of graphite and fulminate of mercury. The mixture is compressed into a cavity into which the fuze terminals slightly project. The electrical conducting power of this mixture is regulated by ramming it as tightly as possible, till it offers the particular resistance desired, the attainment of this object is determined, by keeping a feeble current circulating through the fuze, with a galvanometer in circuit, during the ramming process. In this way he has been able to manufacture fuzes, of very uniform electrical resistance, which can be tested with perfect safety and which fire with great certainty.

The general principle on which some of the most important tests in connection with a submerged charge, are made, is due to that electrical action, which is set up between plates of different metals, when connected together and immersed in sea water. If a plate of zinc and another of copper, for example, be immersed in sea water and connected by a conductor even of considerable length, a very decided deflection will be observed on a moderately sensitive galvanometer, introduced into the circuit. Taking advantage of this circumstance, an arrangement is made

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somewhat similar to that shown in the Diagram: at the home end of the circuit are three earth plates in the sea, one of copper, one of zinc and one of graphite, so arranged as to be easily connected at pleasure to the extremity of the electric cable leading to the mine; in the mine itself is a zinc earth plate, between the shore end and the fuzes, then come the fuzes, and beyond them in the sea water is a carbon earth plate. Disregarding for a moment the branch conductor, leading to the circuit closer, the object of which I hope to explain presently, we have the following results of this combination. When the insulation of the conducting cable is efficient, the mine dry, and the connections and conductivity good, in fact, when everything is in working order, we have three definite and distinct deflections, due to the carbon plate at the outer extremity, coupled through the resistance of the fuze and electric cable, with the zinc, copper or graphite at the home end. In practice we chiefly use the zinc and copper plates at the home end, the graphite being employed for more delicate comparative tests and other purposes. Should any derangement take place, if, for example, the case leaked and allowed water to enter and wet the charge, we should then have an action set up between the earth plate in the charge itself and either of the three plates at the home end of the cable, which could be thrown into circuit at pleasure, the resistance of the fuzes, of which there are two in each charge, connected in divided circuit, being eliminated. (The resistance of these fuzes is considerable: each has a resistance of about 15,000 ohms., which, in divided circuit would give about 7,500 ohms. for the whole, a very large proportion of the entire resistance of the circuit.) A different degree of deflection on the galvanometer would be the result, and the direction in which the needle would be deflected would be modified, in consequence of the zinc plate within the charge, becoming substituted for the original graphite in the combination, before the mine had become wet. Again, if a fault occurred in the insulation of the electric cable, an action would be set up between the exposed copper conductor and either of the three home earth plates, which might be switched into circuit at will, and again a different direction and degree of deflection on the galvanometer would be observed. In this way if anything went wrong with the mine, fuze, or electric cable, the tests would at once indicate it, and with other tests, which I shall now proceed to explain, give to an experienced eye a very fair means of judging of what had actually taken place. We have called this the "Sea Cell Test," and its arrangement is due to the gradual development of the

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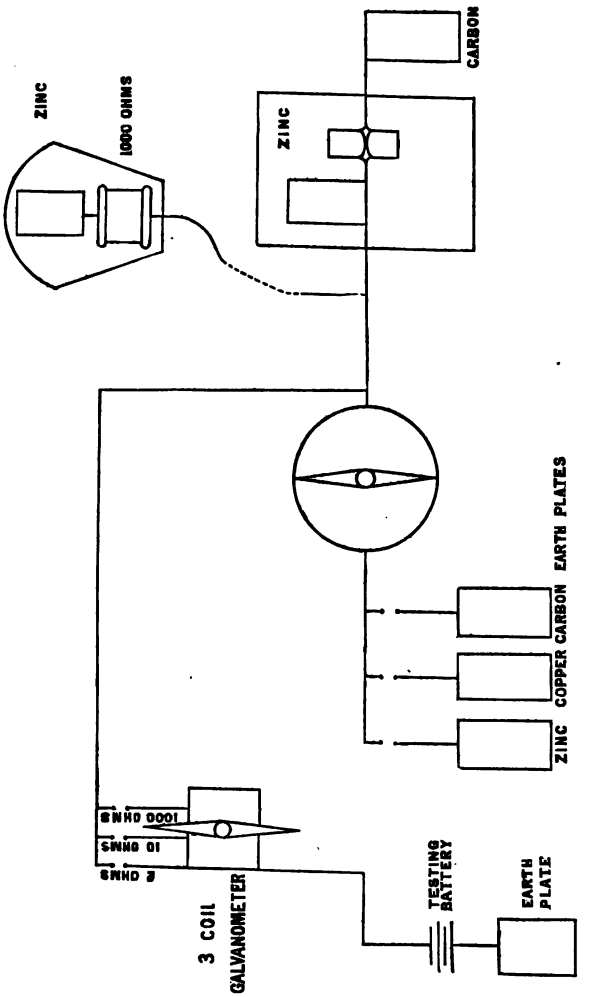
DIAGRAM OF TESTING ARRANGEMENTS.

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system, which has taken place in carrying out experiments in submarine mines. at the School of Military Engineering, at Chatham.

Let us now turn, for a moment, to the arrangement and connections of the branch, by which the circuit closer is combined with the system. This branch is in electrical connection with the main cable and consists of an insulated conductor, the joint with the main cable being also carefully insulated; within the circuit closer is a coil of 1,000 ohms resistance, in direct connection with the insulated branch cable and also with a zinc earth plate. We have thus, from the point where the branch connection is made, two circuits, one through the fuzes and to earth, the other through the resistance coil in the circuit closer and to earth, each through a considerable electrical resistance. With a resistance of 7,500 ohms on one line, and of 1,000 ohms on the other, the combined resistance of the two branches would be 882 ohms, and adding 18 ohms for the resistance of a relay, used for signalling purposes in the circuit, and about 14 ohms for the electric cable, &c., we should have a total resistance of about 914 ohms for the whole combination. The object of this arrangement is to preserve the means of testing, not only through the fuze but through the connections of the circuit closer. The mode in which the circuit closer acts to fire the mine is very simple. A small battery, of two Daniell's cells, is kept constantly on the main line to the mine, through a relay; as long as the resistance in the divided circuit, shown in the diagram, is opposed to the passage of the current of this small battery, it has not sufficient energy to form an electro-magnet, by its action on the coils of the relay, of sufficient power to attract the armature. On a vessel striking the circuit closer, however, the 1,000 ohms coil is, for a moment, cut out of circuit and a connection made direct to earth; the relay then acts and throws a powerful firing battery into the circuit, and the moment the direct earth connection with the circuit closer is broken, and the 1,000 ohm coil again thrown into circuit, a proportion of the current of the firing battery passes through the fuze and fires it.

The second mode of testing, which is shown in the diagram, by means of a three coil galvanometer, was suggested by Mr. Brown, of the Chemical Department, Royal Arsenal, Woolwich. The galvanometer has only one needle, the coils being wound on over it, one outside the other. The 1,000 ohms coil is inside, next to the magnetised needle, the 10 ohm coil is next, and the 2 ohm coil outside. 1,000 ohms was selected for long coil, in order to bring it nearly equal to the combined resistance

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of the circuit to be tested, which you are aware is about 914 ohms. The 10 ohm coil and the 2 ohm coil are intended to give results for comparison, and to come into play when any fault, which greatly reduces the resistance of the system, occurs. For testing purposes, two Daniell's cells are used in connection with this galvanometer. When everything is in good order, the three coils are switched into the circuit, one after the other, and three definite deflections are observed on the needle. Should any defect occur, an alteration would at once take place in the deflections obtained, and by a comparison of these, and by means of the sea cell test, a very fair indication is obtained of the nature of the fault existing. For example—supposing the case had become leaky, the earth plate within it, would at once give a strong zinc reading, by the sea cell test, while the deflections on the three-coil galvanometer would give a reading approaching to dead earth; this combination would at once give an indication of a wet charge. With other faults, different combinations would be observed. It is easily understood how, having obtained three definite deflections, when a combination is in good working order, these deflections will be considerably modified should an alteration occur in the electrical resistance in circuit. For example—in either of the contingencies mentioned, viz., a wet charge or a fault in the electric cable, the entire resistance of the circuit would be enormously reduced, and this would produce a considerable increase of deflection, especially when the 10 ohm coil or 2 ohm coil of the galvanometer was put in circuit, the current acting through a comparatively much smaller electrical resistance. This is the principle on which tests with the three-coil galvanometer have been designed.

| READINGS ON THE ASTATIC GALVANOMETER, SEA CELL. | | | READINGS ON THE 3 COIL DETECTOR, 2 CELLS DANIELL. | |
|---|---|---|---|---|
| No. 2. | Zinc Earth. | Copper Earth. | Negative Current. | Positive Current. |
| | At Home. | At Home. | OHMS. 1,000. 10. 2 | OHMS. 1,000. 10. 2 |
| 15 February. | Nil. | 50 Right. | 40. 2. 0 | 44. 2. 0 |
| | | Cable | Parted. | |
| 16 February. | 4 R | 12 R | 55. 25. 3 | 57. 26. 5 |

The foregoing table gives the actual tests taken with the sea cell and three-coil galvanometer, on a perfect and faulty combination. On the 15th

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February, the mine (No. 2.) was in capital working order, as indicated by the tests. During the night, the electric cable was deliberately cut by the crew of a vessel, which had anchored over it, and fouled it in weighing their anchor. The tests on the 16th February, as given, indicate the fact of damage to the combination as well as, to a certain extent, the nature of the damage, viz., an exposure of the cable conductor. All the tests indicate a considerable reduction of electrical resistance, especially noticeable on the 10 and 2 ohm coils of the three coil galvanometer, while the sea cell test indicates, in addition, copper instead of zinc exposed in the sea water. The direction of the deflection, in the sea cell test on the 16th of February, is considerably modified by the polarization of the exposed copper conductor, due to the passage of the current of the battery, used in connection with the shutter or relay, or to that of the testing battery. This effect of polarization is well known and must always be taken into consideration.

A Daniell's battery is used for testing purposes, because the current is of such a nature as to enable it to be passed through a tension fuze with the least possible danger of firing it. Experiment has proved that Abel's submarine electric fuze is quite safe when a test current of two or even more Daniell's cells is passed through it. The working current of a Daniell's cell, of the form used for testing purposes, on short circuit, as compared with that of one of Grove's, of the land service firing battery, is as 1 to 270 nearly.

Before placing fuzes in a mine they should be tested, by being balanced, by means of a Wheatstone's bridge, and when two or more are placed in divided circuit, as those shown in the diagram, they should be selected of nearly equal resistance. Those which we employ for submarine mining purposes are selected with a resistance of, as nearly as possible, 15,000 ohms. Two high tension fuzes, in divided circuit, are always used, so that if, by any accident, one is defective, the other may act and fire the charge. Fuzes possessing an unusually large or unusually small electrical resistance should be rejected. The resistance of the service platinum wire fuze is about ·2 ohms, which rises, when the thin platinum bridge is at the point of fusion, to ·8 ohms. To those who have been in the habit of testing submarine cables, it is scarcely necessary for me to say that the polarization of faults, and even of the earth plates themselves, when subjected to the passage of a continuous current, such as that of the cells of the signalling, or relay, battery, must always be considered in making the tests which I have explained. This polarization, which cannot be avoided,

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has occasionally given us some trouble: on the whole, however, these tests, when made by experienced hands, have proved very satisfactory.

It is a very essential point before making electrical tests of the nature described, or indeed any electrical tests, to see that the galvanometers, batteries, &c., are in working order, and the earth connections good. A false impression may easily be given, and an electrical combination may be supposed to be out of order, when the fault really lies in the testing instruments themselves, or in the earth connections.

In elaborating the details of these tests, every endeavour has been made to combine efficiency with simplicity. They were chiefly worked out in the course of last summer, when I was absent from England, having been employed on special duty on the Continent. I cannot therefore take any credit personally for the results obtained. Such credit is due to the officers attached to the School of Submarine Mining, a branch of the School of Military Engineering, at Chatham, and to those attached to the Torpedo Committee, and especially to Lieutenants Anderson and Armstrong, Royal Engineers, and to Mr. Brown, of the Chemical Department, Royal Arsenal, Woolwich.

There are many other points, connected with the electrical ignition of explosives under water, which are also worthy of attention, as, for example, the mode of firing by detonation, the nature of the explosive, and the strength and nature of envelope or case, &c. Time will not permit of my entering upon a description of these matters on the present occasion. Each one of them would, in itself, give ample scope for a paper, and I hope we shall have something on them from some of our other members, who are better qualified for the task than I am.

Before concluding, I wish to call your attention, for a moment, to a modification of the firing battery for submarine mining purposes, which has been suggested by Quarter-Master Sergeant J. Mathieson, R.E. The original battery is of Walker's pattern, with zinc plates 7 inches by 4½ inches, one zinc, of this size, being attached to two carbons in the adjoining cell, the carbons being half an inch shorter and of the same breadth: the object of reducing the length of the carbons, is to allow of the point of the zinc standing in a little mercury in the bottom of the cell to keep it amalgamated. The exciting liquid is diluted sulphuric acid, one of acid to eight of water. The defect of this battery is the facility with which its plates become polarized when the battery circuit is closed. In order to obviate this, Sergeant Mathieson has enclosed the zinc plate in a flannel bag, in which a quantity of pounded sal ammoniac is placed in

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contact with the zinc. He fills up the outer cell with a mixture of peroxide of manganese and pounded graphite, and uses a saturated solution of sal ammoniac, to replace the diluted sulphuric acid: in fact, he converts the battery into a modified Leclanché.

In this combination, the polarization is immensely reduced, and the heating power, as indicated by the effect of the current upon a thin platinum wire, improved and rendered very much more constant. I have here two specimens of this form of battery, one of large plates, 7 inches by $4\frac{1}{2}$ inches, and one of small plates, 5 inches by $2\frac{1}{2}$ inches. Either of these will fire a platinum wire fuze, the bridge of which is composed of $\frac{3}{10}$ inch of platinum wire, weighing 1-6 grs. to the yard. A ten cell battery with the smaller sized plates, will fire such a fuze through a resistance of 11 ohms.

Batteries of this form are manufactured by The India Rubber, Gutta Percha and Telegraph Works Co., of Silvertown, and are suitable for any purpose where considerable quantity combined with constancy is required. They are very portable, the liquid is not liable to upset, and they would be suitable for sub-marine mining service, either on shore or on board ship, or for such purposes as ringing electrical bells, &c.

In conclusion, I beg to thank the President and those gentlemen, who have been so kind as to honour me with their presence this evening.

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## DISCUSSION ON THE PAPER.

Professor ABEL, F.R.S., said he did not know that he could add to the very interesting communication they had heard on the subject of Electrical Firing, and the methods of testing. The author had referred to the fuze to which he (Prof. Abel) had given considerable attention during the last 15 years, in which he had received the valuable co-operation of Mr. Browne, and there were many interesting points, and some difficulties to be overcome, in the production of these fuzes for the purposes of the Navy, viz., the essential requirement of testing without explosions, and the essential requirement of absolute permanence. The fuze known as the service tension fuze, composed of phosphate of copper and chloride of potash, could be made of remarkable sensitiveness, and the roughest form of pile arrangement could always be relied on to fire these fuzes. To test this fuze it was necessary to use very weak battery power; and

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to overcome the objection against that fuze for submarine mines, experiments were made to obtain a material which uniformly presented greater resistance, and could be tested with greater certainty. That was accomplished in the fuze now used, in which electrical testing could be made with great uniformity by driving it at a maximum pressure; after being compressed, it did not spring again, and the permanent resistance of the fuse was secured, besides which they would depend upon this fuse remaining in a uniform condition under very rough usage. As an illustration of the safety of this fuse, he might state that he had passed a current from 10 medium sized cells of a Daniell battery through it for two days, and a reduced battery had been kept playing through the fuse for several months.

Capt. Dawson, R.N., said he should have felt some delicacy in rising on a purely technical question of electricity in the presence of a number of Electricians had he not been called upon by the President, but he would not offer any observations upon the particular points immediately before them. He had devoted some attention to another branch of this subject in connection with torpedoes. Though he had had no official connection for some years, he had taken great interest in the progress made. He had noticed the great zeal and intelligence of the Royal Engineers, at Chatham, for acquiring under difficulties, and especially pecuniary difficulties, proper appliances in forwarding the interests of science; and his own observation had taught him that a little outside pressure was useful in leading the way. About a year ago, he had the pleasure of hearing Major Stotherd read a paper on a collateral subject, and on that occasion he (Capt. Dawson) offered some criticisms which he could not now repeat, in consequence of practice having removed the objections. One of the great objects to be attained was simplicity in the electrical arrangements, suitable for the rough work of war. He saw in the Mathieson battery, a great improvement upon the batteries for the purposes of war which he saw a year ago, and the testing arrangements seemed to be improved. Another step had been made in the right direction by trying, outside the Medway, torpedoes for a period of six months, and experimenting with them; and he brought it before this Society, because they had volunteers in most arms of the service, but they had not as yet a corps of submarine telegraph engineers ready to undertake the defence of our ports in time of war. In such an event we should want torpedoes at most of our mercantile ports, and the men to arrange them would be Telegraph Engineers. They could bring to bear experience in the laying and



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working of cables under water. If, for instance, Spithead had to be defended, it would take, perhaps, 100 torpedoes, with all the appliances and cables to form one single line, and it would be necessary to form three or four lines, in consequence of the rise and fall of the tide. There would be some 900 cables to be placed, and, therefore, simplicity was of the first consequence, and the experience of submarine engineers would be of the greatest value in laying the cables and testing them when in their places. We were now making torpedoes in large numbers at Woolwich, and placing them in store, and he was glad to find that practical experiments with them were being made at the Nore. But we had not yet gone far enough in that. He wanted to see one port at least put into a condition just as it would be in case of war. If we wanted to defend a port by guns they were placed in position, and a *feu de joie* shewed what could be done with them. He wanted to see such a port as Liverpool or Spithead with all the torpedoes placed in position. Let the torpedoes, for the occasion, be filled with sand, and let a torpedo *corps* be attached to the port for six months, day by day to watch the operations. Then, as a practical finale, say to the navy—"Try and lift these torpedoes without being found out," and on their failure—as was to be hoped it would be—to do that, the next thing he would say was—"Now pass the ships over them without blowing yourselves up." They would thus teach practically the use of these appliances. They saw the difficulty of complicated arrangements, and he was sure, though great progress had been made towards simplicity, there was room for still further improvement; and it was gratifying to find that the Royal Engineers were always ready to go forward in the path of scientific progress.

Capt. MALCOLM said it was gratifying to know that there was, on a small scale, a corps formed for this torpedo work, by whom regular drill was being elaborated, and it was only by strict drill and practice that the simplicity of arrangements which Captain Dawson so warmly advocated could be found out. With reference to that gallant gentleman's observations as to defending ports, he would ask—were we prepared to give up all the commerce of the port? (Capt. Dawson: No.) In time of war H.M. ships would take charge of steam vessels coming in to or out of port, taking them through the lines with special tugs, as, owing to the short distance of the circuit closers under water, the screws might cut them to pieces.

Capt. DAWSON said he wanted the trial to be made in commercial ports

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for our ships going in and out. We must discover how to get our own ships through uninjured, while, at the same time, the enemy's ships would be blown up. That was the problem to be worked out.

Capt. MALCOLM said the difficulty in time of peace would be with the screws of the steamers injuring the apparatus, and they could not allow a screw to go through except being towed by a paddle-wheel tug. One application of this sub-marine mining occurred to him. He was engaged some years ago in Canada, on the St. Lawrence, where there were frequently ice bridges, which were very useful when the ice was hard, but, when the ice broke up, became dangerous and a nuisance. On one occasion, a gentlemen from Quebec borrowed some of the electrical apparatus, and set to work in his own way to blow up an ice bridge, unfortunately out of three charges only one went off. He was convinced from the smash made of the ice, that two or three charges of gun cotton would be of the utmost use in destroying these ice bridges.

PROFESSOR ABEL mentioned that on the last Arctic expedition, ice was blown up by means of dynamite, and a passage for ships was thus effected when necessary.

Major STOTHERD, in reply, said with reference to the passage of ships amongst submarine mines, a group had been prepared in one of the channels at Sheerness—not as many as we wished for—but still sufficient for experimental purposes. Screw steamers passing over them occasionally did some damage. They struck the circuit closers and sometimes injured the outer protecting wooden casing, but never the internal mechanism. If they passed at slow speed, and knew where these things were, they would do very little damage. A paddle steamer was employed there now, and she was sent out occasionally, but she always "slowed" going through the mines. If she went at full speed a certain amount of damage would, no doubt, be done to the circuit closer jackets.

Captain DAWSON remarked that was a serious objection.

Major STOTHERD said it would only be necessary to compel steamers to go through slowly.

THE PRESIDENT, in closing the discussion, said the subject was of very great interest, and one which had partly occupied his attention for a long period. Members might not be aware that the first application of torpedoes and submarine mines was made as early as 1848, in the harbour of Kiel. The torpedoes consisted of bags of gunpowder connected with batteries on land by wires insulated with gutta percha. He believed that was the first application to this purpose of insulated wires. These mines were to be

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exploded when a ship came over them, and the position of the ships was determined by a reflector. In the latter period of the Austrian war a great number of torpedoes were laid, depending upon double action, one contact being established between the ships and the torpedoes and the second contact on land. If both contacts were established the mine would explode, but if one or the other was not in contact it would not explode. He agreed with Captain Dawson that it was altogether a very difficult subject; but a great deal would no doubt be done, and submarine mines would form an essential point in modern warfare, not only for defence but for attack. He would now call upon the meeting to pass a vote of thanks to Major Stotherd for his very interesting paper.

The vote of thanks was unanimously accorded.

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*The following Candidates were balloted for and duly elected:—*

As Members:—

Lieut. G. Barker, R.E., Chatham.
Lieut. T. E. Broadbent, R.E., Calcutta.
S. Brough, Calcutta.
Thomas Deane, Hooper's Telegraph Works, Mitcham.
Capt. S. Eckford, R.E., Calcutta.
B. T. Finch, Calcutta.
Lieut. W. J. Gill, R.E., Aldershot.
George Griffith, Harrow.
Lieut. W. H. Hall, R.N., Storrington, Sussex.
Capt. R. Home, R.E., Topographical Department, War Office.
Col. H. Hyde, R.E., Calcutta.
Lieut. Jelf, R.E., Chatham.
Col. W. F. D. Jervois, R.E., C.B., War Office.
Capt. M. Lambert, R.E., Aldershot.
S. P. Luke, Calcutta.
Charles Reynolds, Calcutta.
Major-General Sir J. L. A. Simmons, K.C.B., Royal Military Academy, Woolwich.
Edward Tansley, Post Office Telegraphs, Edinbro'.
Lieut. K. R. Todd, R.E., Chatham.

As Associates:—

Col. V. Baker, 10th Hussars, St. James' Place.
A. C. Bell, 7, Great Winchester Street Buildings.
W. W. Biddulph, Parliament Street.
J. W. Beckett, Post Office Telegraphs, Lancaster.

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George M. Carr, Post Office Telegraphs, Sunderland.
W. Cooksley, Post Office Telegraphs, Bristol.
R. Cawood, Post Office Telegraphs, Glasgow.
Thomas Dorman, Post Office Telegraphs, Stockton-on-Tees.
Andrew S. Dunn, Caledonian Railway, Glasgow.
A. Flewell, Post Office Telegraphs, Bristol.
J. W. Fletcher, London and North Western Railway, Chester.
James Gibson, Post Office Telegraphs, Edinbro'.
J. W. Hargraves, Post Office Telegraphs, Carlisle.
George Humble, Post Office Telegraphs, Newcastle-on-Tyne.
David Lessels, Post Office Telegraphs, Edinbro'.
J. W Lusty, Post Office Telegraphs, Exeter.
John M'Intyre, Post Office Telegraphs, Aberdeen.
J. E. Naylor, Post Office Telegraphs, York.
H. Richardson, Post Office Telegraphs, Douglas, Isle of Man.
J. Robertson, Post Office Telegraphs, Bristol.
Frank Reid, Post Office Telegraphs, Newcastle-on-Tyne.
R. S. Symington, Post Office Telegraph, Glasgow.
H. Saunders, British Indian Submarine Telegraph Company.
E. A. Stevenson, Telegraph Construction and Maintenance Company, Greenwich.
J. Sax, Great Russel Street.
Von Fischer Treuenfeld, Vauxhall Bridge Road.
C. H. Woollen, Post Office Telegraphs, Exeter.

As Foreign Members:—

David Brooks, New York.
Frank L. Pope, ,,
Alfred Niaudet Bréguet, Paris.

The Meeting then adjourned.

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## THE PRESIDENT'S CONVERSAZIONE.

On Thursday, the 6th June, the Society of Telegraph Engineers, brought their first session to a close by a conversazione given by the President Dr. C. W. Siemens, F.R.S., and which will be long remembered with pleasure by those who were present as a most successful *réunion*.

The meeting was held, by the kind permission of Lord Lindsay, Vice-President, at his laboratory in Greek-street, Soho; the rooms available for the occasion were suitably decorated, and the effect on entering was satisfactory in the highest degree, while the illuminated motto composed for the occasion by Mr. Schutz-Wilson (Secretary), stood prominently forward:

"*The Lords of Lightning we; by land or wave,*
"*The mystic agent serves us as our slave.*"

A very numerous and interesting collection of electrical and telegraphic apparatus was exhibited, but the greatest interest was excited by the huge electro-magnet, the property of Lord Lindsay, who not only designed it, but had it constructed on special principles, principally for dia-magnetic experiments. This electro-magnet is by far the largest yet constructed, and some highly interesting experiments were shown with it with a reduced electro-motive force.

Lord Lindsay also showed his beautiful specimens of the photographs of the late eclipse of the sun, his improved spectroscope, a large 20-inch spark induction coil and a variety of microscopic and other scientific instruments.

Mr. R. S. Culley, C.E., Engineer-in-chief of the Post Office Telegraphs, showed several obsolete forms of telegraph instruments, such as the Cooke and Wheatstone Five Needle Telegraph and others; also a complete set of the various instruments now in use by the Post Office, embracing the single-needle, Sounder, Morse ink writer, the Hughes type-printing, and the Wheatstone automatic apparatus, which latter attracted much attention; several forms of batteries, and the galvanometers and testing apparatus used, were also exhibited.

Messrs. Siemens Brothers showed their electrical pyrometer and deep-sea thermometer, a field service Morse instrument, dynamo-electric machine for firing fuzes, universal galvanometer, Stoehrer double marking instruments, a field service dial telegraph, alternative current key, Indo-European recording instruments, and also a new and compact form of the A B C instrument.

Mr. Latimer Clark showed an instrument for the determination of electric currents in absolute measure, while Messrs. Apps exhibited an electrical ship signalling arrangement, Gordon's electrical anemometer, induction coils, and a very beautiful set of Geissler tubes, put in action by small electro-magnetic engines.

An A B C instrument, type-printer, a special switch, and a bell and a tell-tale A B C were shown by Sir Charles Wheatstone, while Captain Colomb, R.N., and Major Bolton, exhibited their signalling apparatus, as used in Her

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Majesty's Services; Captain Malcolm, R.E., field telegraph instruments, as employed by the Royal Engineer Field Telegraph Corps; Mr. George Henley, a double-marking printer; and Mr. S. Phillips, Jun., a ship and shore testing arrangement to be employed during the paying out of submarine cables; several plumbago resistances, useful for many experiments where high and invariable resistances might be required.

Messrs. Varley showed Jones's A. B. C. instrument; Varley's regulator; vacuum lightning protector; a new pencil writer to do away with the dirty effects of printing ink; this instrument will doubtless be of some advantage if the pencil be made of such material as to mark legibly.

Messrs. Waterlow exhibited in full action their interesting electro-chemical process of printing, and Mr. C. F. Varley exhibited a series of batteries of large power connected to a specially-constructed condenser by the aid of which most powerful disruptive effects were produced.

Sir William Thomson's syphon recorder, as used on the Falmouth and Lisbon cable, was shown in working order by Mr. Gray, and much interest was evinced by it. A special form of tangent galvanometer of Sir William Thomson's was also shown by Mr. Gray.

Mr. G. E. Preece exhibited samples of submarine cables of a very interesting character, as well as some photographs of a travelling van and apparatus designed and used by him for testing underground cables. The Colmar calculating machines were also exhibited, and the facility of manipulating them attracted much attention.

Several other exhibits might be noted; but as the majority were exhibited subsequently at the Royal Albert Hall, the detailed exhibits given in the account of the soirée will suffice for both.

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## SOIRÉE AT THE ROYAL ALBERT HALL, JUNE 18TH. 1872.

The exhibition of Electrical and Telegraphic Apparatus at the President's Conversazione was of so novel and interesting a character as to specially excite the attention of Major General Scott and others connected with the Albert Hall, who in consequence conceived the idea of repeating the "exhibits" at the Royal Albert Hall, supplemented by a short and concise verbal exposition of the apparatus.

Overtures were made to the Society, and on full deliberation by the Council it was resolved that a Soirée should be given under the auspices of the Society, when as complete and as perfect an exhibition of electrical and telegraphic apparatus should be shown as possible. The onerous task of delivering at one of the "Exhibition Soirées," a short lecture on Telegraphy illustrating the Instruments exhibited was unanimously delegated to Mr. W. H. Preece, C.E., of the Postal Telegraph Department. The notes of his lecture and the description of the Exhibits are appended. It is unnecessary for us to express the

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satisfaction generally felt at the success of the evening's entertainment; it is, therefore, considered more advisable that the encomiums should proceed from others, therefore the letter from General Scott, C.B., and two extracts from the daily papers are given.

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## TELEGRAPHY: ITS RISE AND PROGRESS IN ENGLAND.

Notes of a Lecture delivered at the Royal Albert Hall, July 18th, 1872, by WILLIAM HENRY PREECE, Member Inst. C.E. and Soc. T.E., Divisional Engineer, Postal Telegraph Department.

TELEGRAPHY, unlike many of the other arts, cannot be said to owe its development directly to the impulse imparted by the International Exhibitions of 1851 and 1862; though it can be said to do so indirectly by the opportunities then afforded for the display of those foreign improvements which have had such an influence upon its present prosperity. The periods represented by these Exhibitions, however, form epochs in the history of the art which give prominent stand points upon which to base the few remarks that follow.

Commercial Telegraphy itself is an infant of only 26 years' growth; but the first practical form of instrument, in England, was invented by Messrs. Cooke and Wheatstone, in the year 1837. Prior to that period, it was but a scientific toy. On the 25th July of that year a trial was made from Euston to Camden Town through wires 1¼ mile in length, placed underground. It was tried on the Great Western Railway from Paddington to West Drayton in 1838. Mr. G. P. Bidder introduced it practically on the Blackwall Railways in 1840, in working the rope system on that line; and in 1841, Mr. Locke ordered a short line from the Queen Street Station, at Glasgow, to Cowlairs.

In 1842-3, the Great Western telegraph was continued from West Drayton to Slough, to illustrate a new and cheap method of suspending wires in the air. The first form was called the "Hatchment" telegraph, from its resemblance to those strange objects on the fronts of our mansions, which provincials gaze at with so much wonder. Many will remember the intense excitement produced in the public mind by the apprehension of Tawell, the murderer, by means of this very telegraph. A young woman had been murdered on January 1st, 1845. The following message was sent from Slough:—"A murder has just been committed at Salthill, and the suspected murderer was seen to take a first-class ticket for London, by the train which left Slough at 7.42 p.m. He is in the garb of a Quaker, with a brown great coat on, which reaches nearly down to his feet; he is in the last compartment of the second first-class carriage."

Tawell was apprehended, convicted, executed. Few know how nearly the ends of justice were frustrated. The instrument makes no Q or Z. The word QUAKER could only be spelt "KWAKER," and it was with the greatest difficulty that his orthography could be comprehended. It had to be repeated several times, and in consequence it considerably delayed the message.

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In 1843 a short line was erected in Ireland, and another upon the Leeds and Manchester Railway in England; but in 1844, the first line of any length was constructed from London (Nine Elms) to Gosport, upon the London and South-Western Railway.

It was not until 1846, however, that it took root, and that a Company was formed in England for its establishment as a commercial undertaking.

In the year 1851, there were but 1,752 miles of railway covered by telegraphs, and 7,303 miles of wire; the number of stations was 198, and the total number of messages transmitted over these wires during the year was 48,490.

In the year 1862, the miles of line had increased to 12,711, the miles of wire to 57,879, the number of stations to 1,616, and the number of messages transmitted to 2,676,354. In the present year we have about 25,000 miles of line, 87,719 miles of wire, 5,179 stations, and the total number of messages estimated to be transmitted over the Postal Telegraphic system during the year is 15,500,000. One day's messages of the present year exceed those of the whole year 1851. Tabulated this becomes:—

| Year. | Miles of Line. | Miles of Wire. | No. of Stations. | No. of Messages. |
|---|---|---|---|---|
| 1851 | 1,752 | 7,303 | 198 | 48,490 |
| 1862 | 12,711 | 57,879 | 1,616 | 2,676,354 |
| 1872 | 25,000 | *87,719 | 5,179 | 15,500,000 |

The changes effected in the tariff charges to the public for the transmission of messages are not less interesting and instructive.

As an instructive comparison of the rates charged for the transmission of messages in the earlier days of the telegraph and now, it may be mentioned that the charge was,—for a message from London, about 6*d.* per word. The uniform rate *now* per word for the whole of the United Kingdom is ½*d.*, or less than three farthings per word.

In addition to this, addresses which in the early days were included in the message and therefore charged for, and in the latter days were limited to ten words are now sent *free*. The public, however, frequently misuse this privilege. Addresses are made unusually long and precise. The following is a singular instance of this: a message was sent from Sherborne and delivered to—"Jim Pierce, a little boy in charge of horse and gig, in a field called 'Eight Acres,' just above Railway station, Shepton Mallett, belonging to Mr. Giles Farrington Gurney." A direction that will suit a letter will suit a telegram.

An interesting fact to show the growth of telegraphy is this:—In 1849 there were but eight instruments at Lothbury, which was then the head telegraph station of the City, with four or five boys working them—boys by day and men by night. There are now 409 instruments, employing 1,358 hands, of whom 709 are males and 649 females. There were, in 1849, but 408 battery cells. The number of battery cells employed now is 17,000.

* To this should be added about 20,000 miles of wire belonging to the Railway Company, which was included in the return for 1862.

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In 1852 it was mentioned as an extraordinary fact that 1,000 messages passed through the head telegraph office in London in one day. On Feb. 26th, 1872, no less than 28,508 messages passed.

The enormous development of telegraphic business consequent upon the transfer to the State of the telegraphs, is due not only to the reduction of the charges to the public, but to the great extension of the system, to the increased facilities afforded to the public, and to the greatly improved manner in which the messages are transmitted as regards delay and accuracy. There were 2,932 offices open at the transfer, there are now 5,179. Thus 2,247 entirely new offices have been opened by the Post Office. There were prior to the transfer 66,000 miles of wire: there are now 87,719 miles. Thus the Department in two years has erected 21,719 miles of wire. There were taken over from the Companies 2,175 instruments; there are now 8,284. Thus the Department has fixed 6,109 additional instruments. The business is increasing annually at the rate of over 30 per cent. The number of messages per office opened, which at the transfer was 43, is now 49, and this in spite of the addition of so many small offices. The average charge per message *inclusive of porterage* is 1/1¾*d.*; under the Companies it would have been 2/1¼*d.* Thus the public have not only gained a reduction of sixpence per message on the tariff, but sixpence per message on the porterage charges, and porterage charges have nearly disappeared. The public itself is becoming familiarised with telegraphy. The feelings of fear and alarm which once accompanied every telegram, are now more frequently converted into those of surprise and joy, for the wires have become the vehicle of communication as much for our little household joys as for the great concerns of State.

The telegraphs of this country belong to the Nation. Every person has an interest in them The prosperity of this property can be seen by any one every week in the papers, wherein the total number of weekly messages is inserted. 126,000 messages at the transfer have now risen to 308,000, and since every 1,000 messages produces £57 7s. 9½d., the money they bring in can readily be calculated. Indeed, it may be said that in the year that is coming, the telegraphs will unquestionably put £1,000,000 into John Bull's purse.

* * * * * * * * *

Telegraphy does not convey ideas directly by signs or symbols. Hence it is not a language. It merely transmits to distant points the first elements of *written* language—either letters or numerals—by certain preconcerted signals.

The formation of these signals and the methods adopted in their transmission, constitute the different systems of telegraphy.

The signals used are either *visible* or *audible*. The visible signals are either transient or permanent, and differ in *form*, *colour*, or *duration*, and the audible signals, which are always transient, differ in *tone* and *duration*.

They are transmitted by electricity, light, or sound.

The different systems used were then considered from a historical point of view rather than from the more scientific method.

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## I.—The Needle System.

(*a*) This was the first form of instrument used. It was invented by Messrs. Cooke and Wheatstone. The alphabet is formed by the vibrations between two fixed stops of a small moveable pointer, or needle, and its signals are therefore visible and transient.

(*b*) The different forms used in 1851, 1862, and 1872 are illustrated in actual working models. There are 3,582 of these instruments in use by the Postal Telegraph Department.

(*c*) The method adopted in the calling of stations, and in the actual transmission of messages was illustrated.

(*d*) *The rate of working.*—In the first form of the needle instrument the rate of working only averaged about 6 words per minute, but in 1851 the average rate of working, owing to improvements in construction, was 17 words per minute; whilst in 1862, a careful examination made by the then Secretary of the Telegraph Company, showed 21¼ words per minute to be the average rate of sending upon the double needle instrument. The double needle in expert hands could, however, easily attain 40 to 45 words per minute. The single needle, under similar circumstances, frequently reaches 35 words; but it must be remembered that the useful speed of a telegraph instrument, and particularly the needle form, is limited by the rate at which a man can write. A casual examination of the work transmitted over such a circuit at the Southampton station proved it now to be 25 words per minute. When it is remembered that this work is transmitted over only one wire, and that the double needle required two for its use, it will be seen that a marvellous improvement has been effected in the rate of working needle instruments. The same wires that in 1851 conveyed 17 to 20 words per minute now transmit from 50 to 80 words per minute.

(*e*) The temporary character of its signals, and the very small difference between one letter and the next require considerable experience and quick sight to avoid error in the transmission of messages. For instance the letters X and Y are very similar on the double needle. Thus an anxious husband was very much startled to learn that his wife had presented him with a "box." E, F, and G are nearly the same. A learned barrister had forgotten his wig; his secretary was mystified by the request to send him "my wife in a bandbox." And a station master, who had been requested to search for a "black box" *in a first-class carriage*, replied that he could not find the "black boy" *anywhere*.

There is but one double needle circuit left in the Postal Telegraph System, and this form is gradually being replaced on the railways by the more convenient single needle. Its disappearance is regarded with great regret by old telegraphists, for as a conversational instrument it is superior to all other systems, and many fast and lasting friendships have been made by its agency between those who have never met. Two officers at the end of the same wire are

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practically in the same place. Distance and separation are of no consequence. Space is annihilated. All the variations of temper, mood, character, and nature are as evident 200 miles off as though the companion were in the same room. Marriages have been arranged between those who have never seen each other.

## II.—The "Morse" System.

(*a*) The principle of the Morse instrument is the well known dot and dash alphabet. This alphabet is illustrated by diagrams and is produced not by the alternation of the current, as in the needle system, but by its varying duration. It is a *recording* instrument, registering its signals by visible and permanent marks, and it thus differs entirely from the needle system, which is based on transitory visual signals.

(*b*) The form first used in England was that known as the "Bain's" instrument, which registered its dot and dash by the precipitation of Prussian blue upon chemically prepared paper, on the passage of the currents. In 1862, this form was supplanted by the true "Morse" apparatus, which recorded its characters by the indentation or embossment of paper, but in 1872, this has again been replaced by the more finished and elegant ink writer, recording its character in ink, which is now in universal use. There are 1,509 of these instruments in use by the Postal Telegraph Department.

(*c*) The method of working the Morse printing circuit, &c., was illustrated.

(*d*) *The rate of working*—In 1851, a careful examination of Bain's circuit showed that it registered its messages at the rate of 19½ words per minute; in 1862, the average rate of working on the Morse recorder was about 20 words a minute. A casual examination of the way in which the working is done at the Southampton office by the "Inker" showed that the rate at which messages were transmitted, was now from 35 to 40 words per minute, and on a very recent occasion, 37 messages were received in 32 minutes, on two different wires on the same day in the ordinary course of business. Messages average 34 words, including the ordinary service signals. There were, therefore, 39·3 words per minute transmitted.

(*e*) The defects of this system are few, and may principally be those inseparable from the human machine. The instrument itself will record messages faster than a clerk can send or write. Errors, also, frequently arise, not only from the tiring of the clerk, but from the necessary transitory character of the force sent, particularly in this moist and variable climate, and the great similarity of the signals sent. Thus H and S, P and G have only the difference of a dot, and thus, a gentlemen who had telegraphed for his "hack" found to his annoyance a "*sack*" waiting his arrival at the station. Another who had sent for a "gig" found a "*pig*." Another who had forgotten his "cocked hat" received by parcel a "*cooked ham*."

Such errors are not altogether due to the apparatus, to the manipulator, or to the system. Many senders write very badly. Little care is exercised in the

writing, wording, or punctuation. Thus the physician was hurried away with the message, "Don't come too late," which should have been "Don't come; too late." Had this been "Too late—don't come," or "patient's dead: don't come," a useless journey might have been saved.

The manager of one of our leading newspapers was surprised to find an advertisement sent by telegraph for insertion, concluding with these words "Friends will accept this remittance by post." *Intimation* and the full stop were omitted.

Every form of telegraphy is actuated by transitory pulsations of force, and most of them are read by arbitary symbols. Errors are inherent to every system of telegraphy, and all the care and supervision which can be exerted will not entirely remove them. There is one error arising from different causes in every 300 messages. They can only be reduced to a minimum. The principal remedy rests with the public itself. It must be recollected that unless messages can be signalled with considerable rapidity, cheap telegraphy would be utterly unremunerative. A slow telegraph is a contradiction in terms. Moreover, a signaller is placed in the position of a person who writes and is unable to see what he has written. Few persons are able even to copy a document rapidly or to write letters six or eight hours a day without making some error. They can correct in reading over what has been written. The telegraphist cannot do this.

Senders of messages should word them carefully, write them clearly, and educate themselves in brevity and perspicuity.

## III.—Automatic Apparatus.

It has already been mentioned that the human machine tires, and as a consequence makes errors. Errors mean repetitions and delays. Moreover, the limit of speed attainable by the human machine is soon reached. Signals can be made to follow each other on the simple Morse apparatus much quicker than clerks can manipulate or write.

(*b*) Several forms were exhibited in 1862, but, Bain's excepted, no other form has been used in England, except the beautiful apparatus of Sir Charles Wheatstone, which is now extensively employed by the Postal Telegraph Department. It consists of three parts, the *perforator* which prepares the message, by having a series of holes punched in stiff paper ribbons; the *transmitter* which sends, and the *receiver* which receives it, as in the Morse system.

(*c*) The method of working the apparatus was exhibited in full working order.

(*d*) *Rate of Working.* Although a wire worked with the Morse apparatus has transmitted on an abnormal occasion, with specially skilled operators, 82 messages per hour, and it *could* maintain this speed, the average over the

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system is not more than from 30 to 35 per hour. The Automatic, on the contrary, could transmit experimentally 300 messages per hour. Generally it may be said that the Automatic apparatus has doubled the capacity of all our long wires and quadrupled that of our shorter wires and there is no doubt that it is capable of much further improvement and development.

(*e*) *Defects and errors.* The system, however, is not without its defects. Although a greater amount of work is got through the wires, it is at the expense of delay.

We are not entirely freed from the liability of human mistakes. Wherever we are subject to the action of the will we are liable to error. The method of punching is not an exception. Dots are punched for spaces, spaces for dashes, and so on.

During the progress of the Tichborne case the following strange announcement was made:—"*Even Billy* complained of the excessive heat, and the Court thereafter adjourned." The Lord Chief Justice's indignation at this freedom with his name could, however, be appeased by the information that "*Even Billy*" was punched for "eventually."

(*f*) The great advantage of this system, apart from the extreme clearness and accuracy of the messages sent by it, the increased capacity it imparts to the wires, and the possession of a machine that never tires, is the fact that the same message can be repeated as often as is necessary. In the transmission of news—a most important branch of the Postal Telegraph system—this is invaluable, for the same punched strip can be passed through several instruments successively, and the same transmitter can actuate the receivers at several stations. Thus, one transmitter at Telegraph-street works the receivers at Bristol, Exeter, Plymouth, Gloucester, Newport, Cardiff, and Swansea; another works those at Nottingham, Sheffield, Leeds, and Newcastle; and another those at Birmingham, Manchester, and Liverpool; and the same punched strip will actuate all, though of course not simultaneously.

Without its aid it would have been impossible to have carried the enormous amount of news supplied to the provincial press. On March 7th, 331,384, and on March 19, 362,732 words were sent from the Head Telegraph Station alone. Assuming 350,000 to be the number sent, this means that nearly one million words are transmitted all over the country; and this is equal to 500 columns of the *Times*.

The transmission of news is done at a rate less than *one penny* per line, and it produces a revenue of £47,420.

The Queen's speech on the opening of the present Session of Parliament, was sent to nearly 200 towns in the United Kingdom. It contained 1,780 words. The length of the printed ribbon was 111 yards. It was sent on the Morse at the rate of 42, and on the Automatic at the rate of 94 words per minute.

There are now 33 circuits working automatically in the Post Office Telegraph Department.

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### IV.—Dial Telegraphs.

(*a*) This is the simplest of all forms of telegraph for reading despatches. It consists of a dial upon which the letters of the alphabet are placed, and before which a pointer is rotated, stopping at the letter required to be indicated. This pointer is propelled by currents of electricity. Thus words are directly spelt letter by letter, and any person who can read or write, can send and receive messages with this instrument.

(*b*) The form in use in 1851 was very crude and rough compared to those exhibited in 1862, and in use at the present time. The same refinement of workmanship and beauty of mechanism, which are so characteristic of the other systems, are very conspicuous here. Instruments of each period were exhibited. There are 2,367 instruments of this kind in use by the Postal Telegraph Department.

(*c*) The method of working was shown in practice. Every instrument is provided with a bell to attract attention, and it does not, therefore, require that constant watching so necessary in the needle system.

(*d*) The rate of working is slow. Very expert manipulators attain sometimes 20 words per minute, but the average rarely reaches 10 words per minute, indeed, 4 or 5 words per minute is the usual pace.

(*e*) It, however, requires no batteries to work it, the power being extracted from magnets, and it is always ready and is easily maintained. This, combined with its simple manipulation, renders it highly useful and advantageous for private telegraphy, for which purpose it is very largely used. No private wire existed in 1851. In 1862 there were 177 miles of wire, and 183 dial instruments. In 1872 the private wire department of the Post Office Telegraphs draws in no less an income than £48,790, and in its management there are no less than 4,468 miles of wire, 1,767 dial telegraphs, and 234 other forms of instruments.

### V.—Printing Telegraphs.

(*a*) This term is applied to those instruments which print messages in bold Roman type upon strips of paper, the printed slip itself being cut off and delivered to the receiver.

(*b*) Two or three forms were exhibited in 1851, but none were practically used. In 1862 several were exhibited. Only one however has practically been adopted in England. This is Hughes's, which is now employed by the Postal Telegraph Department, twenty-three of them in daily use.

(*c*) The method of working was shown.

(*d*) The rate of working is very fast. The Queen's speech was transmitted to Liverpool at the speed of between thirty-six to thirty-seven words per minute. Between London and Newmarket an average of fifty-four per minute was sent, and it has done over sixty in the minute.

### VI.—Acoustic Telegraphs.

(*a*) These instruments convey their intelligence by the ear. They are non-

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recorders. All other instruments convey their signals through the eye, but these instruments signal their messages either by the difference or by the duration of sound The alphabet is in each case based upon that of Morse. A bell of one note signifies a *dot*, of another note a *dash*; or a sharp stroke, equivalent to a crotchet, on a species of sounding-board, is a *dot*, and a long-dwelling sound, equivalent to a minim, a *dash*.

(*b*) No instrument of this class was exhibited in 1851 but in 1862 Bright's Acoustic Telegraph was exhibited, and was then largely in use in England. Although still partially in use, it is gradually being removed owing to its complexity, and the more simple American form of Sounders, which retains the peculiarity of the Morse alphabet, is being introduced. These forms were exhibited. There are 394 Bells and 211 Sounders in use by the Postal Telegraph Department.

(*c*) They are worked in precisely the same way as the Morse instruments.

It has been impossible in this brief sketch to make any allusion to the forms of batteries from whence this marvellous power is obtained, or to show the various improvements that have been effected in their construction during the periods selected for comparison; nor can I allude to the equally important accessories to telegraphy relays, and lightning protectors, which of themselves would form a subject for an evening's discourse; nor to the many useful appliances apart from the mere transmission of messages, viz., the transmission of correct time to all parts of the United Kingdom, the firing of guns, the wonderful power it places in the hands of railway managers for the regulation of their traffic and the preservation of the lives of their passengers, the registration of the meterological changes from all points of our coasts, nor have I been able to allude to the progress made in submarine telegraphy, which was not in existence during the first Exhibition of 1851, and which is gradually connecting together all the continents of the World in one united family.

But does not the question arise, to whom are we indebted for the possession of this new highway of thought? I answer, first to Messrs. Cooke and Wheatstone—to Sir William Fothergill Cooke, principally for the energy, determination, and patience with which he practically introduced and established it; to Sir Charles Wheatstone especially, who has devoted a lifetime to those profound researches which, aided by a fine inventive genius, have chiselled a rough stone into an exquisitive piece of sculpture; to Morse (who has but recently departed this world), for the invention of a universal Telegraphic Code, and the recording form of apparatus; to John Lewis Ricardo, whose enterprise, perseverance, and fine administrative abilities, inaugurated a system of Commercial Telegraphy; and to Mr. Frank Ives Scudamore, who has concentrated the labour of a lifetime into three short years to consolidate that system and to establish the Electric Telegraph as a grand imperial undertaking, making it a credit to the country, a source of profit to the nation, and an example to the world.

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## EXHIBITION OF ELECTRIC AND TELEGRAPHIC APPARATUS, AT THE ROYAL ALBERT HALL, ON THURSDAY, THE 18TH JULY, 1871.

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Exhibited by FRANK IVES SCUDAMORE, C.B., Vice-President Society Telegraph Engineers.

Fossil Telegraph, 1837.
Code Table, 1841.
Cooke and Wheatstone's original Needle Telegraph, 1837.

| | | | | | |
|---|---|---|---|---|---|
| Do. | do. | four | ,, | ,, | 1841. |
| Do. | do. | double | ,, | ,, | 1846. |
| Do. | do. | ,, | ,, | ,, | 1850. |
| Do. | do. | ,, | ,, | ,, | 1851. |
| Do. | do. | large | ,, | ,, | ,, |
| Do. | do. | ,, | ,, | ,, | 1862. |
| Do. | do. | small | ,, | ,, | ,, |
| Do. | do. | single | ,, | ,, | ,, |
| Do. | do. | ,, | ,, | ,, | 1872. |

Three single Needle Instruments were arranged as a speaking circuit in the Hall.
Two Magnetic Telegraph Company's Single Needle, 1851.
Two Henley's Magneto-electric Double Needles.
,, Henley's ,, ,, Single Needles.
Single Needle Train-signalling Instrument.

| | | | |
|---|---|---|---|
| Large Six do. | do. | do. | Norwich. |
| Large Five do. | do. | do. | Blackwall Railway. |
| Large Clock-face | do. | do. | South Western ,, |

### Recording Instruments.

Two Bain's Electro-chemical Printing Telegraph, 1851.
Bain's ,, bath ,,
Two Morse Recorders.
Two early Forms of Inkers.
Digney's Morse Ink Recorder, 1862.
Two Siemens' Direct Ink Writer, 1873; (these were worked as a circuit.)
One Siemens' Local Ink Writer, 1872, with relay, galvanometer, and key complete.
Theiler's (early form) Type Printing Instrument.
Two Hughes' Type Printing Instruments, 1872 (these were worked as a circuit).
Two Wheatstone's fast speed Automatic Ink Recording Instruments, with puncher, transmitter, and receiver complete.

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### Alphabetical Instruments.

Wheatstone's A B C instrument, 1840.
Do. do. do. 1862.
Do. do. do. 1872.
(A circuit was worked with the present form of A B C instrument.)

### Acoustic Instruments.

Bright's Bells, 1862.
Do. do. 1872, P.O. pattern.
American Pony Sounder.
Direct Sounders, P.O. pattern.
Translating Board for insertion in the middle of a long line for the reproduction of signals, so as to avoid manual re-transmission, and prevent delay.
Varley's 4-wire Lightning Protector, 1862.
Do. do. do. 1872.
Do. (Boxwood and Carbon) do. for single needles.
Do. do. for A B C.

### Batteries.

Gutta Percha Sand Battery, 1851.
Daniell's Battery 1862.
,, ,, Chamber 1872.
,, ,, Ordinary ,,
Leclanché's Manganese Battery,,
Magnetic Telegraph Co.'s Battery.
United Kingdom ,, ,,

### Insulators.

A collection of various Telegraph Insulators employed at different times by the several Telegraph Companies and by the Post Office.

### Testing Apparatus.

1851.

Wheatstone's original Resistance Coils.
Ordinary detectors.

1862.

Ordinary detectors.
Varley's Differential Galvanometer.
,, Resistance Coils.

1872.

Ordinary detectors.
Station Galvanometer.
Tangent do.
Wheatstone's Bridge and Resistance Coils.
tatic Galvanometer in case for above.

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Thomson's Reflecting Galvanometer, with lamp and scale, and shunt box.

Testing Keys, battery, and discharge.

Condenser, for measurement of capacity.

Small Reflecting Galvanometer, for use in travelling van on tripod; for testing underground wires.

Delicate Astatic Galvanometer.

Commutators, for changing battery, altering power, and direction of currents.

Three Photographs of interior and exterior of travelling van used for testing underground wires.

Four Photographs of the process adopted in preserving telegraph poles by injecting sulphate of copper.

### Exhibited by A. APPS, 488, Strand.

Vacuum Tube, "Good Night" in very large letters. Constructed of *uranium* glass, and exhausted to a high degree, requiring only one eighth of an inch spark to illuminate it.

Electrical Egg of 9 inches diameter, arranged to show the discharge by induction from one pole of Apps' patent 10-inch Spark Coil.

A Large Gassiot Cascade.

Two Smaller Cascades, illuminated with the above in series.

A 10-inch Spark Patent Induction Coil.

A Small Coil on same patent principle, with 6-inch sparks. Electro-motive force of five Grove's cells.

A small 2½-inch Spark Coil, with two small bichromate of potash cells.

Electro-magnetic Engine, arranged for the Sewing Machine, requiring no intermediate cranks or wheels, the band passing direct and the proper speed insured.

A Series of Glass Cells, Bichromate Battery, illustrating the prevailing forms in use, and the progress made in their manufacture.

A Small Electro-magnetic Vacuum Tube Rotator of peculiar design, so arranged as to work both ways.

A 30-inch Black Polished Disc of Vacuum Tubes, arranged in an ornamental design, rotating at various speeds by an electro-magnetic engine.

De Wilde's electrical Probe and Forceps, as used in H.M. Hospitals, and by the Prussians during the late war.

Improved Ship's electric telegraph, for giving orders to the steersman and engineer.

Chinese Heads, and ornamental vacuum tubes in fluids, combining most of the rarest devices and colors.

A black board of stratified and phosphorescent Geissler Tubes of the newest designs; also tubes with strontium and barium sulphates, remaining luminous many minutes after discontinuance of electric spark.

Wheatstone's Bridge, of a new pattern, containing all the advantages of the shunt systems, with a means of ascertaining their condition.

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Exhibited by WATERLOW & SONS, London Wall.

Patent Electro-chemical Copying Press, in working order.

Exhibited by C. F. VARLEY, F.R.S., M.S.T.E.

Double disc Holtz Electrical Machine.

A Battery of 1000 cells with condensers specially constructed, the enormous power of this battery was shown by deflagrating metal, and by other experiments.

Exhibited by WILLIAM LADD, Beak Street.

A double 24 inch Holtz Electrical Machine.

An Electric Light *(used during the Lecture)*.

Two Large Tuning Forks, moved by electricity, three feet long, with a cord stretched between them 15 feet long; this cord showed the compound vibration of the forks, the cord illuminated by the Electric Light.

Exhibited by MATTHEW GRAY, M.S.T.E.

For the India Rubber, Gutta Percha and Telegraph Works Co., Silvertown.

Sir William Thomson's Syphon Recorder.

" " Quadrant Electrometer.

Preece's Single Wire Railway Block Signal Instruments.

Specimens of Submarine Cables:—

West India.
Dublin and Holyhead.
Hebrides.
Japan.
Torpedo Cables.

Specimens of native insulating material unmanufactured:—

Gutta Percha.
Balata.
India Rubber.

Specimens of above manufactured for Telegraphic purposes.

Exhibited by W. T. HENLEY, M.S.T.E.

Case of samples of various Submarine Telegraph Cables manufactured by him.

Large permanent Magnet.

Exhibited by S. E. PHILLIPS, JUN., M.S.T.E.

An arrangement for testing Submarine Cables during the operation of paying out, showing the electrical connections on ship and shore.

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Exhibited by CHARLES BECKER, M.S.T.E., for ELLIOT BROS.

Winter's Frictional Electrical Machine.
Large Induction Coil.
Various Instruments used in testing Submarine Telegraph Cables.
Reflecting Galvanometers.
Resistance Coils.
Wheatstone's Bridge.
Wheatstone's Bridge and Resistance Coils combined.
Condensers for the measurement of the Electrostatic Capacity of Cables.
Contact, Short Circuit and Discharge Keys.
Commutators, for altering direction of Currents.

Exhibited by SIR CHARLES WHEATSTONE, F.R.S., M.S.T.E.

Automatic fast-speed Printing Instrument.
Keys for testing purposes.
Double Current Keys.
Electrical Relays.
Rheostat, for measuring small resistances.
Galvanometers.
Magnetic Deep Sea Thermometer.
Do. Counter and Magnet Machine.
Do. Type Printer.
Do. Bells and Tell-Tales.
Do. A B C Instrument.
Do. Exploder and Fuzes.
Do. Wire Pull.
Switch for A B C Instruments.
Tell-Tale for do.

Exhibited by O. and F. H. VARLEY, M.S.T.E.

T. and F. H. Varley's Pencil Writer, Morse Printing Machine.
T. and F. H. Varley's Regulator Relay, for controlling the amount of Current flowing through Coils, and regulating the Magnetism in the Iron Cores.
T. and F. H. Varley's Double Current Key.
C. F. Varley's Vacuum Lightning Protectors, with Aluminium Guarded Conductors.
A pair of Alphabetical Instruments.
A pair of Railway Block Instruments, for working direct, without Local Battery, combining a single-stroke Bell and Indicator, and requiring but one Line Wire.

Exhibited by MESSRS. SEIMENS BROS., M.S.T.E.

Indo-European Automatic Inker.
Indo-European Line Inker, without clock work.
Direct Inker.

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Indo-European double Current Key.
Siemens' and Halske ,, ,, ,,
Post Office ,, ,, ,,
Direct Sounder, with movable Electro-Magnet and Galvanoscope.
Field Service Inker (Prussian pattern).
Bipolar Relay under glass case.
Alphabetical Dial Instrument, with finger keys, on stand.

Exhibited by MAJOR FRANK BOLTON and CAPT. COLOMB, R.N.

Electric Lamp.
Telegraph Codes.
Naval and Military Signalling Apparatus.

Exhibits, illustrative of Flashing Signals.

Complete Night Signal Apparatus, used in the Royal Navy.
Night Signal Apparatus for the Mercantile Marine, using the Chatham Light.
The Chatham Light in another form.
The Chatham Light for use in shore stations signalling to sea-ward.
Model shutter apparatus for shore stations.
Model Collapsing Drum for Ships.
Signal Horn.
Group of Signal Books.
Signal Flags on Poles.

Exhibited by LORD LINDSAY.

Various Electrical Apparatus, Electromagnets, &c., &c.

Exhibited by MAJOR MALCOLM, R.E., for the War Department.

500 lb. Mine complete with Electric Cable and Anchor.
Apparatus to shew Firing Mine, with a fuze in Circuit and Battery.
Test table, with fittings complete.
Signalling Apparatus.
Coil Platinum Wire.
Fuzes, Platinum Wire and Tension.
Battery Firing, Mathiesons, 10 cells.
Ditto Portable.
Recording Instruments, Military Pattern.
Sounding do. do.
Magnet Transmitter.
Dynamo-Electric do.
Electric Lamp.
Von Ebnor Frictional Exploder.
Ebonite Jointer, with wire.
Specimen of fuzes of kinds.
Captain Mallock's Telegraph Pole, complete.
Polarized Sounder for India.
10 cell Signalling Battery.
Lamp Signalling, Walker's.

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# ORIGINAL COMMUNICATIONS.

Cape of Good Hope Telegraph Company, Limited,
Cape Town, 18th May, 1872.

To the President of the "Society of Telegraph Engineers," London.

Sir,—By a recent mail I received a copy of the rules and regulations of the Society of Telegraph Engineers, together with your inaugural address, and I welcome with satisfaction the formation of a society having for its object the advancement of electrical science, and the interchange of communication regarding the working of the telegraph among its members. I should very much wish to become a foreign member, and be glad to forward any observations worthy of notice respecting telegraphy in this colony.

The lines of this Company which are under my charge are in length 760 miles, and although erected nine years ago, no further extensions have taken place; yet with the discovery of diamonds and the improved state of the finances of the colony I have every reason to believe that soon extensions in the direction of the diamond fields will be carried out, and ultimately to Natal, which is to be the starting point of the projected cable to connect the South African colonies with Aden, *vid* Bourbon, Mauritius, and Seychelles.

I have the honor to be, Sir,
Your most obedient servant,
JOHN D. DEN, General Manager.

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To the Secretary of the "Society of Telegraph Engineers."

Battle, Sussex, July 4th, 1872.

Sir,—I have not met with any statement in English histories, or other English treatises, on the Electric Telegraph, relative to *Volta's* proposed Electric Telegraph.

Professor L. Magrini, member of a committee appointed to examine and report upon Volta's library, manuscripts, and instruments, published a paper in

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the "Alti del Rle. Istituto Lombardo," vol. ii., entitled. *Notizie, Biografiche, e Scientifiche su Alessandro Volta.* This paper was read at various times, in 1861, at the said institute. It contains a paragraph, of which the following is a literal translation:—

"An autograph manuscript, dated Como, 13th April, 1777, which is suspected (and the suspicion was confirmed by one of the sons of Volta) to have been addressed to Professor Barletti, contains various experiments on his pistols, and the singular proposition, very remarkable for that time, of transmitting signals by means of ordinary Electricity. Besides the figure, there are particulars conducive to its practical application."

"This letter is of the greatest interest for the history of the science, inasmuch as it indicates the first bold and certain step in the invention and institution of the Electric Telegraph."

Although our Charles Marshall, of Renfrew, in 1753, and others, forestalled this proposition, it is interesting, as proving that the *in re electrica Princeps* believed in the efficiency of frictional electricity for the purpose.

I am, Sir, your obedient servant,

G. E. Preece, Esq. FRANCIS RONALDS.

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## ANNUAL INTERNATIONAL EXHIBITIONS OF SELECTED WORKS OF FINE ART (INCLUDING MUSIC), INDUSTRIAL ART, AND RECENT SCIENTIFIC INVENTIONS AND DISCOVERIES.

Upper Kensington Gore,
London, S.W., 20th July, 1872.

Sir,—I am directed by Her Majesty's Commissioners to request that you will be so good as to convey their thanks to the President and Council of the Society of Telegraph Engineers, and to those gentlemen who kindly lent telegraphic instruments for exhibition on the occasion of Mr. Preece's lecture in the Royal Albert Hall, on the 18th instant, on the "Progress of Telegraphy in England, and the present condition of electric science."

I have the honor to be, Sir,
Your obedient servant,
HENRY Y. D. SCOTT, Major-General,
Secretary.

The Secretary Society of Telegraph Engineers.

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# ON COMBINING DIFFERENT SO-CALLED CONDENSERS TO OBTAIN ANY DESIRED ELECTRO-STATIC CAPACITY.

By Robert Sabine.

The extension of the law of Galvanic Circuits to problems of accumulation, which seems to me to be a necessary consequence of Faraday's theory of induction, was first pointed out distinctly about ten years ago by M. Gaugain, and was subsequently enlarged upon by Mr. F. C. Webb; but has never been taken advantage of practically in testing rooms.

In the exact adjustment of the mica plates of so-called condensers to a required capacity as well as in measurements of Cable Core, the want is frequently felt of some desired measure for comparison, different from those in our possession.

Some months since I had occasion to employ induction apparatus of this kind in delicate experiments which required more various capacities than were afforded by the number of so-called condensers I possessed. In consequence of this, I was compelled to make combinations. I found, however, that although scanty information existed about the theory of what was termed the application of Ohm's law, nothing whatever had been done towards experimentally investigating its truth.

Before taking the applicability of this law on trust, I therefore, instituted a series of measurements which it may be worth while to put on record.

The induction apparatus with which I made the experiments is commonly known amongst Telegraph Engineers as the "Condenser." It consists of leaves of tin foil, separated by the interposition of plates of thin mica, and an insulating cement.

Instead of the word "Condenser," which is wrongly used as applied to this form of induction apparatus, I shall, in the following paper, make use of the word "Accumulator" as preferable.

A "*Condenser*" is an induction apparatus, so arranged that, when charged to a given potential, its electro-static capacity can be suddenly decreased (generally by increasing the distance between its plates), and thus the tension of its charge proportionately increased. Such an apparatus was invented by Æpinus, and was used by Volta in his experiments.

An "*Accumulator*," on the other hand, is an induction apparatus which only collects a charge of electricity. It is so arranged that its electro-static capacity remains unaltered, and therefore the electricity communicated to it, as it undergoes no condensation, is always of the same potential as that of the source. A Leyden jar is therefore an accumulator and not a condenser.

The molecules of an insulating body, interposed between conductors whose potentials are different, become polarized to a greater or less degree, according to the *inductive resistance* of the material. By *inductive resistance* is understood that quality of a dielectric in virtue of which it constructs the complete polarization of its atoms, by a given difference of potential between its two sides, and this inductive resistance is different in different materials.

The reciprocal of the *inductive resistance* of a body is what is called its *inductive capacity*; or the facility which it offers for induction.

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The specific inductive capacities of various bodies were approximately determined by Faraday and Snow Harris, who referred them to atmospheric air as unit.

It is much more convenient, however, in practice to express the specific inductive capacities of materials, as well as the inductive capacities of bodies in the units of electrical measurement which have been recommended by the Committee on Electrical Standards appointed by the British Association.

I find it convenient to express the specific inductive capacity of any insulating material in terms of the quantity of electricity which a plate one square foot coated-surface and one thousandth of an inch (or one mil) thickness is capable of containing, when the inductive surfaces have a difference of potential of one volt. The unit of measurement by which the quantity of electricity thus contained is measured, is called a "*microweber*," and the capacity is then expressed in what are called "*microfarads*."

Thus the specific inductive capacity of air would be 0·0323; that of bee's-wax, 0·0601; that of india-rubber 0·0904 microfarads; that is to say, a square foot of India-rubber $\frac{1}{1000}$ of an inch thick, would have an inductive capacity of 0·0904 microfarads; or, in other words, one of its surfaces would contain just 0·0904 microwebers more than its other surface, if the difference of potentials between the two surfaces were 1 volt.

In order to find out, what the behaviour of any system of accumulators would be when connected up in cascade or otherwise, we need only supplement the laws of capacity by the following law of inductive resistance:—

"If two or more accumulators be connected with each other in cascade, their resultant inductive resistance will be equal to the sum of their several inductive resistances when separated."

The inductive resistance of an accumulator (such as is commonly used in cable measurements), whose capacity is $\frac{1}{3}$ microfarad, is 3; therefore, if two such accumulators be connected up in cascade, their combined *inductive resistance* will be 6; and the electrostatic capacity of the combination will be only $\frac{1}{6}$ of a microfarad, or one half the capacity of either of the accumulators taken separately.

In the same way an accumulator whose capacity is 0.5 microfarads has an inductive resistance = 2: and if this be connected in cascade with the accumulator whose capacity is $\frac{1}{3}$ microfarads, their combined inductive resistance will be $2 + 3 = 5$, and their combined capacity in this position will therefore be $\frac{1}{5}$ of a microfarad.

And, generally, if the capacities of any number of Leyden jars or other accumulators be respectively $a, b, c, d \ldots\ldots n$, their resultant electrostatic capacity when connected up in cascade will be:—

$$\frac{1}{\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d} + \ldots\ldots + \frac{1}{n}}$$

Which means that the electro-static capacity of two or more accumulators in cascade, is equal to the reciprocal of the sum of the reciprocals of their several capacities.

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To prove it experimentally I provided myself with the following accumulators:—

**A.** Mica (No. 7) insulated with cement, made by Messrs. Warden & Co., the property of Sir Samuel Canning.

**B.** A similar accumulator (No. 20), the property of the West India and Panama Telegraph Company.

**C.** Mica (insulated with paraffin) made by myself.

**D.** Mica (No. 19), the property of Messrs. Warden & Co.

**E.** Old Mica, insulated with wax, the property of Mr. Latimer Clark.

The measuring instrument used in these experiments was Thomson's astatic reflecting galvanometer, the shunt resistances for which were taken from a box of adjusted coils.

The observations were made with the help of a discharging key; the accumulators were allowed to charge fully from the element by direct contact with its two poles for a minute, then the key was depressed by which the connection with the element was broken; at the same instant the galvanometer was connected between the charged sides of the accumulator. The readings taken were the distances travelled by the spot of light on the galvanometer scale. In all the experiments I used a Daniell's element of the Minotti form.

Before commencing this series of experiments, I satisfied myself by repeated trials that the galvanic element was sufficiently constant, and that the deflections given by the spot of light were proportional to the quantities of electricity discharged through it.

*Exp.* 1.—Accumulators separately.

| Positions. | Shunted. | Observed throw. | Inductive Capacity. |
|---|---|---|---|
| | $\frac{9}{10}$ | divisions. | microfarads. |
| A | | 116 | a = 0.3333 |
| B | $\frac{9}{10}$ | 116 | b = 0.3333 |
| C | none | 300 | c = 0.0862 |
| D | $\frac{9}{10}$ | 174 | d = 0.5000 |
| E | none | 218 | e = 0.0626 |

*Exp.* 2.—All Accumulators connected up parallel.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| $+ \left\{ \begin{matrix} A \\ B \\ C \\ D \\ E \end{matrix} \right\} -$ | $\frac{19}{20}$ | 229 | 1.316 |

Calculated $a + b + c + d + e = 1.315$ microfarads.

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*Exp.* 3.—Accumulators in Cascade.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| + A B C D E — | None | 99 | 0.02845 |

Calculated $\dfrac{1}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}+\frac{1}{e}}$ = 0.02818 microfarads.

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*Exp.* 4.—Four Accumulators parallel with one in Cascade.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| + { A, B, C, D } .. E — | None | 210 | 0.0603 |

Calculated $\dfrac{1}{\frac{1}{a+b+c+d}+\frac{1}{e}}$ = 0.0598 microfarads.

---

*Exp.* 5.—Three Accumulators parallel, in Cascade with two parallel.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| + { A, B, D } .. { C, E } — | $\frac{1}{2}$ | 229 | 0·1319 |

Calculated: $\dfrac{1}{\frac{1}{a+b+d}+\frac{1}{c+e}}$ = 0·1319 microfarads.

---

*Exp.* 6.—Two Accumulators parallel, in Cascade with two others parallel and one single.

| Position. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| + { A, B } { C, E } .. D — | $\frac{1}{2}$ | 169 | 0.0971 |

Calculated:— $\dfrac{1}{\frac{1}{a+b}+\frac{1}{c+e}+\frac{1}{d}}$ = 0·0978 microfarads.

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*Exp.* 7.--Similar arrangement to Exp. 6.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| $+\left\{\begin{matrix}A\\B\end{matrix}\right\}\ \left\{\begin{matrix}D\\E\end{matrix}\right\}\ C$ | None. | 236 | 0·0678 |

Calculated $\dfrac{1}{\dfrac{1}{a+b}+\dfrac{1}{d+e}+\dfrac{1}{c}}$ = 0·0672 microfarads.

*Exp.* 8.—Double Cascade Combination.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| $+E..\left\{\begin{matrix}A..B\\..D..\end{matrix}\right\}..C-$ | Name. | 120 | 0·0345 |

Calculated $\dfrac{1}{\dfrac{1}{e}+\dfrac{1}{\dfrac{ab}{a+b}+d}+\dfrac{1}{c}}$ = 0·0344 microfarads.

*Exp.* 9—Accumulators separately again (taken with different Galvanometer).

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| | | divisions. | microfarads. |
| A | $\frac{9}{10}$ | 138 | a = 0.3333 |
| B | $\frac{9}{10}$ | 138 | b = 0.3333 |
| C | $\frac{1}{2}$ | 178 | c = 0.0860 |
| D | $\frac{14}{15}$ | 138 | d = 0.5000 |
| E | $\frac{1}{2}$ | 130 | e = 0.0628 |

*Exp.* 10.—All parallel again.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| $+\left\{\begin{matrix}A\\B\\C\\D\\E\end{matrix}\right\}-$ | $\frac{35}{36}$ | 151 | 1·313 |

Calculated $a + b + c + d + e$ = 1·315 microfarads.

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*Exp* 11.—Combination of parallel and cascade.

| Positions. | Shunted. | Throw. | Capacity. |
|---|---|---|---|
| $+ \left\{ \begin{matrix} \text{D} \left\{ \begin{matrix} \text{E} \\ \text{A} \end{matrix} \right\} \text{B} \\ \ldots\ldots \text{C} \ldots\ldots \end{matrix} \right\} -$ | $\frac{5}{6}$ | 151 | 0·2188 |

Calculated $\dfrac{1}{\frac{1}{d} + \frac{1}{a+e} + \frac{1}{b}} + c = 0.2189$ microfarads.

After each test a reading was taken with Accumulator D, to see that no change had occurred in the constant of sensibility of the galvanometer.

The formulæ by which these electro-static capacities are calculated, and which agree in all cases sufficiently well for the various combinations, are the common formulæ for shunt or derived circuits, the positions of which are analogous only in which $a$, $b$, $c$, $d$, $e$ are resistances instead of capacities.

I venture to suggest that a more general recognition and employment of the application of this law to inductive circuits would be found of great practical value in the various measurements to which Accumulators are applied.

ROBERT SABINE.

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## EARTH CURRENTS, AND THE AURORA BOREALIS OF 4TH FEBRUARY.—No. 2.

IN calling attention, in the first number of our Journal, to the extraordinary earth currents attending the great Auroral display on February 4th, I delayed concluding the paper in the hope of receiving further information on the subject. I was not disappointed, for since the publication of that paper I have received some valuable records from the Astronomer Royal, which must be acknowledged to be most complete and invaluable, as representing faithful records of the magnetic and electric disturbances of what has been characterized as the greatest storm ever known.

I received the following letter from the Astronomer Royal:—

"Royal Observatory, Greenwich,

"August 6th, 1872.

"Dear Sir,—I have with great interest read several parts of the 'Journal "'of the Society of Telegraph Engineers, No. 1.' In page 114 you say that "'if any of my readers should happen to procure any definite information "regarding these earth currents, I should be very glad indeed to receive them.'

"We possess most perfectly definite and complete information regarding "them. I do not send you the results at this moment, because an alteration "has been made in our instrumental adjustments, requiring an alteration of "computation, for which I await the return of my Mr. Ellis (now absent). But I very much wish that you could run over here any morning to look at our

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"records of earth currents, and to see the apparatus which gives them. I am "confident that they would interest you much.

"I am, dear Sir,

"Yours faithfully,

"G. E. PREECE, Esq." "G. B. AIRY.

I took an early opportunity of availing myself of the Astronomer Royal's kind invitation, and was greatly gratified with the beauty and excellence of the arrangements for enabling photographic records to be made of the movements of the several Magnetometers, and of the Galvanometers placed in the circuit of the "Earth Current" wires; however, as the description of these instruments, and the general arrangements at the Royal Observatory, must necessarily be somewhat lengthy, I am compelled by a want of space to delay giving such a description until our next number.

Subsequent to my visit, the Astronomer Royal was good enough to send me tracings of the photo-records, accompanied by the following letter:—

"Royal Observatory, Greenwich,
"August 29th, 1872.

"Dear Sir,—I enclose to you copies of our photographic records of the "various magnetic disturbances in the great magnetic storm of February 4th. "Pray take care of them, for they have cost us some trouble.

"They deserve to be framed and glazed, as registers of the greatest magnetic disturbance, I think, that we have known.

"I am, &c.,

"G. E. PREECE, Esq." "G. B. AIRY.

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The tracings forwarded were exact copies of the actual photographic records of the three Magnetometers, viz., the Horizontal Force, the Vertical Force, and the Declination Magnets; and also of the N.S. and E.W.* earth current wires, and together form a most interesting study of the changes during the storm. The records are reliable, as the Instruments are self-registering, each Instrument having a mirror, which reflects light on to photographically prepared paper placed on a cylinder, which revolves every twenty-four hours.

These tracings have been lithographed and copies are attached to each number of the Journal, and they will doubtless form an object of great attraction to the members of the Society. They are very valuable, and the Society should consider itself most fortunate that, by the kindness of the Astronomer-Royal, it has been enabled to obtain them.

Sheet 1, gives the curves formed by the earth currents on two wires, placed so that their centres meet near the Observatory (a diagram showing the direction of these wires will appear in our next number). The North-South Wire

* These letters are used here and in subsequent parts of this paper, though not strictly correct. The line called N.S. points about 35° 10′ East of North, and the line E.W. about 26° 30′ South of East.

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commences in a copper earth plate buried at Angerstein's Wharf. N. of the Observatory, and terminates at an earth plate at Lady Well, S. of the Observatory. The East-West Circuit commences at Blackheath, and terminates at North Kent Junction, west of the Observatory. The wires connecting the N.S. and the E.W. earth plates are looped into the Observatory, and a small horizontal galvanometer is placed in the circuit of each, about midway between the earth plates. Straight lines drawn from the earth plates N. to S., and E. to W., bisect each other at a point very near to the observatory, so that the galvanometers situated in the magnetic Observatory are nearly in the centre of the direct line of the earth plates. The record is photographed by means of a bright light reflected from a mirror attached to the magnet of the galvanometer.

The indicated time commences in each case at mid-day of the 4th February.

Sheet 1.—Shows the records of the earth-currents only during the storm; it will, in the first place, be noted that both galvanometers were affected simultaneously, and that also (comparing this sheet with the others) the relation between the movements of the galvanometer and the magnetometer is singularly coincident. The earth-currents seem almost immediately and very suddenly to have appeared in their maximum force, and to be beyond the recording range of the galvanometer; from the commencement to 6.30 p.m. the sheets were without record, from that time until 10.10 the record comes a little frequent, indicating negative currents from the S.E.; the N.S. wire being more affected shewed that there was a little more south than east in the direction of the currents. From 11.0 p.m. the records are perfect and indicate most faithfully the direction and the sign of the currents, from these it will be seen that the sign kept changing most rapidly from negative to positive and back again. The force varying also.

It will be noticed in every case that the force of the current constantly varies and never remains constant at one potential. The behaviour of the current seems to be invariably as follows: starting from the zero line, the force of the current gradually increases until it arrives at its maximum—the time taken in arriving at the maximum varies considerably, in some cases almost instantaneous, in others apparently slow—so soon as the maximum is reached, the force begins at once to decrease until it again becomes zero—without apparently any rest, it at once changes its sign and increases in force until the maximum of the opposite sign is arrived, when the decrease again goes on. A careful examination of the tracing will show the rapidity of these changes in the force of the currents. If the electro-motive force of the currents remained at any time constant, the records, instead of showing vertical or diagonal lines, would show a true horizontal line, the length of the line indicating the time during which the force of the current remained constant; but in no one instance can a horizontal line be detected, proving beyond doubt, that the currents are not only constantly changing in direction and sign, but also in their electro-motive force.

Sheets 2, 3, and 4 represent respectively the records of the Vertical Force

Magnet, the Horizontal Force Magnet, and of the Western Declination. In these the greatest effects appeared to have taken place after 6 p.m., when at 6.22 p m., the Western Declination was as much as 21° 23′ or more than two degrees beyond the minimum declination; this is a greater variation than has hitherto been observed.

The numerical values of the several curves have been calculated; and by the kindness of the Astronomer Royal and of Mr. Glaisher, F.R.S., I am enabled to place before my readers tables (see pp. 255 & 256), giving the numerical values of the indications of the several Magnetometers.

The several places mentioned in Journal No. 1 as having observed the earth currents at different times I have carefully examined, and have endeavoured, by reducing their times all to Greenwich mean time, to notice whether the actual speed of these currents could be determined.

The following are the results—

| PLACE. | LONGITUDE. | | | MEAN TIME. | |
|---|---|---|---|---|---|
| | ° | ′ | | H. | M. |
| Duxbury ... ... ... ... | 71 | 54 | W. ... ... | — | |
| St. Pierre .. ... ... ... | 70 | 35 | „ ... ... | — | |
| Valentia .. ... ... ... ... | 10 | 17 | „ ... ... | 6 | 3 |
| Haverfordwest ... ... ... | 4 | 58 | „ ... ... | 2 | 30 |
| Brest ... ... ... ... ... | 4 | 29 | „ ... ... | 2 | 40 |
| Greenwich ... ... ... ... | 0 | 0 | „ ... ... | 2 | 25 |
| Rome ... ... ... ... ... | 12 | 29 | E. ... ... | 4 | 40 |
| Malta ... ... ... ... ... | 14 | 39 | „ ... ... | 4 | 31 |
| Pera ... ... ... ... ... | 28 | 59 | „ ... ... | 4 | 34 |
| Alexandria ... ... ... ... | 29 | 50 | „ ... ... | 5 | 16 |
| Aden ... ... .. ... ... | 44 | 57 | „ ... ... | 3 | 30 |
| Ispahan ... ... ... ... ... | 51 | 46 | „ ... ... | 5 | 33 |
| Jask .. ... ... ... ... | 57 | 48 | „ ... ... | 3 | 4 |
| Bombay ... ... ... ... ... | 72 | 53 | „ ... ... | 2 | 39 |

From the above times it will be seen that the results are very contradictory, and, therefore, cannot be relied upon; the effect of earth currents would be immediate on such delicate instruments as those employed at the Royal Observatory, but would take time to show themselves on such instruments as are employed in ordinary telegraph offices; besides, immediately such signs occur, the clerks are at once busily engaged in endeavouring to restore communication, and notes cannot well be taken, consequently it is impossible to tell whether the times noted were at the beginning or the middle, or at what period of the disturbance; for such purposes as I have stated these times appear valueless.

However, there are certain points which come out conclusively that is, the direction of the earth currents, and their strength. The direction of these currents was from the S.E. to the N.W., this is shown by the reports from Jask and Ispahan, and also from Constantinople; but the strongest proof is given in M. Tarry's and M. Le Verrier's reports. The first states, "The "direction of the currents was generally from East to West, and linrs perpen- "dicular to this direction suffered least, which besides made themselves felt

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"even on the shortest lines." M. Le Verrier's report, "Let me add, in con-"clusion, that, according to a despatch received from the Director of the Tele-"graph lines, the earth currents began to be felt from 3.30 p.m., first upon the "Eastern lines, Germany and Austria; towards 4 o'clock, the Swiss lines were "affected, and the phenomenon successively came nearer Paris, in passing "through Switzerland by Besançon and Dijon. At 5 o'clock, the wires sur-"rounding Paris were themselves similarly affected."

Those circuits in England lying N.W. and S.E. were most affected, and a reference to the diagram of the earth currents taken at Greenwich shew that the direction of the currents was generally in that direction. With a little care and method, the direction of each wave might be taken from the photo-records. The earth-plates represent four principal points. Any currents coming exactly between two of these points, say S.E. to N.W., would affect the galvanometers equally, as may be seen by reference to the curves; but if the direction, instead of being from the S.E., were from S.S.E. or E S.E., then in the first case the N.S. earth-wire would shew a greater deflection than the E.W; in the second case the reverse would be the effect. It will be seen, therefore, that by a careful measurement of the relative effects upon the two galvanometers, the true direction of the four earth-plates being known, it is possible to compute the true direction of a current at any moment of time.

The force of the currents during this storm appears to have been very great indeed, strong sparks being emitted, the greatest force being noticed at the ends of submarine cables. In the Persian Gulf Mr. Fahie obtained sparks from the cable which were stronger than the spark he obtained from 80 Minotti Cells. Mr. Saunders at Suez observed that the currents in the Red Sea Cable were equal to 170 Daniell's Cells, and at Valentia, on the Atlantic Cable, Mr. Graves measured the force as equal to 59 Minotti's Cells, and remarks "there is no doubt that the force had been more than it was at 5.30 p.m., when measured by me." On the French Atlantic Cable the force was measured at 90 Minotti Cells.

It may, therefore, from the results be noticed that this storm has been about the most severe and most general of any hitherto observed; such an occurrence as almost every telegraphic circuit throughout the world being broken down at the same time is almost, if not quite, unprecedented; and it is a matter of regret that sufficiently definite and reliable details have not been received.

There are several points which, on the appearance of a magnetic storm or of earth currents, should be carefully noted, as they may be valuable—the exact time of their first appearance, duration, and cessation; their direction and their force. These are not difficult matters to observe, and they may, in the recurrence of another storm, prove of value, and help to elucidate the question of earth currents.

In our next number I hope to give some description of the apparatus and means adopted at the Royal Observatory for observing, not only the action of earth currents, but also the effect of magnetic storms. G. E. Preece.

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# ROYAL OBSERVATORY, GREENWICH.

## INDICATIONS OF THE MAGNETOMETERS FOR THE 4TH FEBRUARY, 1872.

| Greenwich Mean Solar Time. | Approximate Western Declination. | Greenwich Mean Solar Time. | Horizontal Force in terms of the whole H.F. uncorrected for Temperature. | Greenwich Mean Solar Time. | Vertical Force in terms of the whole V.F. uncorrected for Temperature. |
|---|---|---|---|---|---|
| d. h. m. | ° ′ | d. h. m. | | d. h. m. | |
| Feb. 4 0 0 | 19 42 | Feb. 4 0 0 | 0.1478 | Feb. 4 0 0 | 0.0350 |
| 1 8 | 19 44 | 0 50 | 0.1482 | 2 27 | 0.0354 |
| 1 38 | 19 47 | 1 13 | 0.1476 | 2 30 | 0.0358 |
| 1 50 | 19 46 | 1 50 | 0.1487 | 2 47 | 0.0353 |
| 2 20 | 19 48 | 2 20 | 0.1489 | 3 15 | 0.0372 |
| 2 25 | 19 44 | 3 6 | 0.1596 | 3 21 | 0.0362 |
| 2 30 | 19 51 | 3 10 | 0.1572 | 3 46 | 0.0385 |
| 2 57 | 19 19 | 3 24 | 0.1610 | 3 52 | 0.0375 |
| 3 13 | 19 38 | 3 31 | 0.1578 | 3 53 | 0.0393 |
| 3 18 | 19 22 | 3 43 | 0.1624 | 3 59 | 0 0374 |
| 3 44 | 20 6 | 3 56 | 0.1466 | 4 5 | 0.0394 |
| 3 53 | 19 26 | 4 7 | 0.1606 | 4 13 | 0.0387 |
| 4 14 | 20 20 | 4 19 | 0.1472 | 4 21 | 0.0399 |
| 4 24 | 20 8 | 4 36 | 0.1600 | 4 26 | 0.0387 |
| 4 37 | 20 20 | | † | 4 43 | 0.0418 |
| 4 47 | 20 4 | 4 55 | 0.1633 | | † |
| 4 48 | 20 17 | 5 15 | 0.1418 | 4 53 | 0.0420 |
| | † | 5 18 | 0.1446 | 4 55 | 0.0347 |
| 6 5 | 19 45 | | † | 5 0 | 0.0380 |
| 6 22 | 21 23 | 5 31 | 0.1406 | 5 1 | 0.0385 |
| 6 50 | 20 10 | 5 34 | 0.1632 | 5 7 | 0.0340 |
| 7 0 | 20 17 | 5 45 | 0.1422 | 5 11 | 0.0296 |
| | † | 5 49 | 0.1622 | 5 22 | 0.0414 |
| 7 15 | 20 3 | 5 52 | 0.1530 | 5 24 | 0.0290 |
| 7 27 | 20 33 | 5 58 | 0.1574 | | † |
| 7 45 | 19 43 | 6 1 | 0.1490 | 5 51 | 0.0290 |
| 7 53 | 20 9 | 6 7 | 0.1594 | 5 56 | 0.0268 |
| | † | 6 13 | 0.1420 | 6 0 | 0.0294 |
| 8 24 | 19 55 | 6 20 | 0.1579 | 6 4 | 0.0260 |
| 8 30 | 20 0 | 6 25 | 0.1460 | 6 5 | 0.0292 |
| 8 40 | 19 27 | 6 27 | 0.1526 | 6 10 | 0.0261 |
| 9 1 | 20 14 | 7 0 | 0.1272 | 6 12 | 0.0311 |
| 9 7 | 19 56 | 7 20 | 0.1452 | 6 17 | 0.0239 |
| 9 11 | 20 17 | 7 22 | 0.1412 | 6 23 | 0.0314 |
| 9 18 | 19 42 | 7 25 | 0.1452 | 6 28 | 0.0257 |
| 9 40 | 20 5 | 7 33 | 0.1366 | 6 48 | 0.0275 |
| | † | 7 48 | 0.1632 | 7 0 | 0.0222 |
| 10 0 | 19 24 | 7 51 | 0.1518 | 7 42 | 0.0375 |
| 10 5 | 19 29 | 8 0 | 0.1648 | 7 47 | 0.0343 |
| 10 9 | 19 18 | 8 7 | 0.1508 | 7 59 | 0.0370 |
| 10 30 | 19 49 | 8 19 | 0.1722 | 8 2 | 0.0360 |
| 10 48 | 19 36 | 8 25 | 0.1596 | 8 8 | 0.0380 |
| 10 55 | 19 42 | 8 30 | 0.1657 | 8 13 | 0.0357 |
| 11 5 | 19 36 | 8 36 | 0.1584 | 8 20 | 0.0380 |
| 12 17 | 19 54 | 8 42 | 0.1639 | 8 30 | 0.0360 |
| 12 46 | 19 38 | 8 45 | 0.1555 | 8 47 | 0.0402 |
| 13 5 | 19 46 | 8 49 | 0.1639 | 8 53 | 0.0318 |
| 13 39 | 19 34 | 8 55 | 0.1566 | 9 7 | 0.0368 |
| 13 50 | 19 37 | 9 6 | 0.1617 | 9 10 | 0.0354 |
| 14 5 | 19 34 | 9 10 | 0.1562 | 9 13 | 0.0359 |
| 14 20 | 19 43 | 9 14 | 0.1626 | 9 2 | |

The Symbol † denotes that the Register has been lost, in consequence of the rapidity of the movement of the magnets.

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# ROYAL OBSERVATORY, GREENWICH.

## INDICATIONS OF THE MAGNETOMETERS FOR THE 4TH FEBRUARY, 1872.

| Greenwich Mean Solar Time. | Approximate Western Declination. | Greenwich Mean Solar Time. | Horizontal Force in terms of the whole H. F. uncorrected for Temperature. | Greenwich Mean Solar Time. | Vertical Force in terms of the whole V. F. uncorrected for Temperature. |
|---|---|---|---|---|---|
| d h m | ° ′ | d h m | | d h m | |
| Feb. 4 14 37 | 19 36 | Feb. 4 9 34 | 0.1512 | Feb. 4 9 30 | 0.0317 |
| 15 0 | 19 48 | 9 44 | 0.1647 | 9 35 | 0.0306 |
| 15 16 | 19 39 | 9 47 | 0.1587 | 9 37 | 0.0323 |
| 15 26 | 19 50 | 9 53 | 0.1705 | 9 42 | 0.0256 |
| 15 30 | 19 43 | 10 12 | 0.1470 | 9 55 | 0.0392 |
| 15 35 | 19 50 | 10 18 | 0.1560 | 10 7 | 0 0376 |
| 15 57 | 19 33 | 10 43 | 0.1392 | 10 17 | 0.0391 |
| 16 14 | 19 43 | 10 57 | 0.1446 | 10 31 | 0.0375 |
| 16 23 | 19 32 | 11 7 | 0.1396 | 10 54 | 0.0396 |
| 16 37 | 19 39 | 11 16 | 0.1442 | 11 3 | 0.0385 |
| 16 44 | 19 34 | 11 26 | 0.1415 | 11 14 | 0.0394 |
| 16 48 | 19 39 | 11 42 | 0.1444 | 11 43 | 0.0382 |
| 16 51 | 19 34 | 11 45 | 0.1416 | 11 57 | 0.0391 |
| 16 55 | 19 39 | 11 50 | 0.1445 | 12 27 | 0.0375 |
| 17 2 | 19 33 | 11 53 | 0.1410 | 12 28 | 0.0386 |
| 17 6 | 19 38 | 12 0 | 0.1472 | | * * * |
| 17 11 | 19 33 | | * * * | 13 40 | 0.0366 |
| 17 15 | 19 40 | 12 49 | 0.1392 | 13 44 | 0.0371 |
| 17 19 | 19 31 | 13 4 | 0.1428 | | * * * |
| 17 22 | 19 39 | 13 20 | 0.1392 | 14 32 | 0.0363 |
| 17 27 | 19 31 | | * * * | 14 55 | 0.0375 |
| 17 32 | 19 37 | 14 12 | 0.1406 | 14 56 | 0.0364 |
| 17 38 | 19 30 | 14 25 | 0.1392 | 15 0 | 0.0371 |
| 17 43 | 19 44 | | * * * | | * * * |
| 18 8 | 19 33 | 14 52 | 0.1416 | 19 0 | 0.0358 |
| | * * * | 15 0 | 0.1392 | 22 0 | 0.0355 |
| 18 33 | 19 40 | | * * * | 23 0 | 0.0356 |
| 18 39 | 19 34 | 15 26 | 0.1444 | | |
| | * * * | 15 38 | 0.1403 | | |
| 19 30 | 19 39 | 15 50 | 0.1449 | | |
| | * * * | | * * * | | |
| 20 23 | 19 36 | 16 24 | 0.1412 | | |
| | * * * | | * * * | | |
| 21 13 | 19 38 | 17 27 | 0.1472 | | |
| 21 23 | 19 35 | 17 39 | 0.1430 | | |
| 21 35 | 19 39 | 17 43 | 0.1476 | | |
| 22 3 | 19 36 | | * * * | | |
| 22 22 | 19 40 | 18 12 | 0.1430 | | |
| 22 38 | 19 37 | 18 15 | 0.1468 | | |
| 22 56 | 19 40 | | * * * | | |
| 23 0 | 19 38 | 18 45 | 0.1440 | | |
| 23 10 | 19 40 | | * * * | | |
| | | 19 30 | 0.1463 | | |
| | | 21 24 | 0.1449 | | |
| | | 21 39 | 0.1461 | | |
| | | 22 0 | 0.1438 | | |
| | | 22 20 | 0.1466 | | |
| | | 22 58 | 0.1442 | | |
| | | 23 5 | 0.1457 | | |

The symbol * * * denotes that the magnet has been generally in a state of agitation.

G. B. AIRY.

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# ABSTRACTS AND EXTRACTS.

## ON A NEW PHENOMENON OF PHOSPHORESCENCE PRODUCED RY FRICTIONAL ELECTRICITY.

By M. ALVERGNIAT.

We make a vacuum, by means of the mercurial air-pump, in straight tubes of glass 45 centims. long; we then introduce a small quantity of chloride or bromide of silicium, and continue the exhaustion till the pressure is reduced to 12 or 15 millims., after which we close the tube at the lamp.

If the tube thus prepared be then rubbed between the fingers or with a piece of silk, a bright glimmer within the tube is seen to follow the movement of the rubber; it is rose-coloured with the chloride, and greenish yellow with the bromide of silicium. It recalls that which has long been observed in the barometer, but it is brighter.

We will remark that, if we try to cause the spark of the induction-coil to pass in these tubes, it developes no light there, unless the vacuum be more perfect; but then the phosphorescence excited by the friction disappears.

We owe our thanks to M. Friedel for the preparation, in a state of purity, of the substances which have given this result.—*Comptes Rendus de l'Acad. des Sciences.*

## ON A COLLECTOR FOR FRICTIONAL MACHINES.

By Dr. H. EMSMANN.

From observing how effective the condenser is when applied to Ruhmkorff's coil, notwithstanding the small space that it occupies, I was led to imagine that a compendious *collector*, which would nevertheless increase the effect considerably, might, in like manner, be adapted to the ordinary frictional electrical machine.

In this I have been completely successful. At an inconsiderable outlay I have attained what the remarkable and comparatively expensive ring (now, however, disproportionately expensive) produces when adapted to Winter's electrical machine.

My original idea was to form the collector of a *single* long strip of tinfoil to be folded up between two overlapping strips of waxed paper, and which



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would be enclosed in a cover of similar material of about octavo size. I purposed placing this collector on the conductor itself of the machine (like Winter's ring), or on the metallic portion between the conductor and the points.

M. Kuhlo, the assiduous and skilful philosophical instrument maker of this place, to whom I addressed myself to carry out my idea, has now executed the *collector* in this way—namely, by inserting into each other several glass tubes hermetically sealed at one end, the diameter of the widest tube being about 2 inches.

With the exception of the widest, which serves simply as an insulating cover, all the tubes, varying in number from three to five, are coated externally with tinfoil applied with paste; the edges of their open ends lie in the same plane; and at those ends all these tinfoil coatings are united together and brought into metallic connexion with the conductor of the machine, the arrangement being such that the collector can be adapted thereto or removed at pleasure.

The effect produced is astonishing. The *collector* accomplishes even more than Winter's ring does when placed, instead thereof, upon a machine furnished with such a ring.

This simple and inexpensive *collector* can be easily adapted to any frictional electrical machine; so that with every such machine we may obtain in an easy and cheap manner similar effects to those for which Winter's ring was so remarkable.—*Phil. Mag.*

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## DEMAGNETIZATION OF ELECTRO-MAGNETS.

By Robert W. Willson, Junior Class, Harv. Coll.

Wiedemann has shown (*Pogg. Ann.* vol. c. p. 235, *Ann. de Min.* (3) vol. l. p. 189) that the intensity of the current necessary to demagnetize a steel magnet is much less than that of the current by which the bar was originally magnetized.

It has occurred to me to experiment with a view to ascertaining how far this principle can be applied to electro-magnets.

The apparatus used consisted of a cylindrical bar of soft iron 8 centims. in length and 1 centim. in diameter, slightly rounded at the end. The armature was a piece of soft iron of the same diameter and 2 centims. in length.

Around this core were placed two concentric helices, wound in opposite directions, through each of which could be passed the current of a single Grove's cell.

The method of experimenting was as follows. A current was first passed through the inner helix, which, for convenience, I shall call A, and the weight supported by the bar was noted. This current being broken, the outer helix,

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B, was introduced into the circuit, and the corresponding weight noted. The current through B being then broken, and that through A closed, after a short time the current was again passed through B and the weight noted. The following Table shows the results:—

| | Wt. supported by | | |
|---|---|---|---|
| | A | B. | A diminished by B. |
| | 490 grms. | 250 | 130 |
| | 470 | 240 | 130 |
| | 460 | 230 | 130 |
| | 460 | 220 | 120 |
| | 420 | 220 | 130 |
| | 410 | 200 | 110 |
| Mean ... | 452 | 227 | 125 |

Taking the mean result, we see that while the helix B can only develope sufficient magnetism in the bar to render it capable of sustaining 227 grms., yet, if it act in opposition to A, it can diminish the weight which the latter supports by 327 grms.; that is, its power to demagnetize is greater than its power to magnetize.

If, then, we suppose the coercive force of the steel bar used in Wiedemann's experiments to be represented by the helix A, and the demagnetizing current of feeble intensity to be represented by the helix B, of less magnetizing power, we have here an interesting confirmation of Wiedemann's results; while we may also extend the application of the principle to electro-magnets, and may assert, in general, that a current of given intensity, or a helix of given dimensions traversed by a constant current, has greater power to demagnetize than to magnetize. It is evident that the case of demagnetizing an electro-magnet by a current is more difficult than the process of demagnetizing a steel bar; for whereas in a steel magnet the resistance is simply the coercive force of the steel, so that the bar when partially deprived of its magnetism has no tendency to return to its original state, even if the demagnetizing current be broken, in the case of electromagnets the helix, by which the bar was originally magnetized, is still acting with its full power when the demagnetizing helix is introduced into the circuit.

A natural inquiry was this: if the bar were magnetized by the weaker helix B, and then demagnetized by the helix A, what additional amount of magnetism could A impart to the bar? It is evident that this case, though somewhat similar to the former is not identical with it; here the helix B acts as resistance to the magnetization of the bar, while, in the former case, it acted to deprive the bar of a portion of the magnetism which it already possessed.

Accordingly the bar being magnetized by B, was submitted to the action of

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A, and the weight supported being noted, the reverse operation was performed, and the weights supported compared as follows:—

| A demagnetized by B. | B demagnetized by A. |
|---|---|
| 85 | 65 |
| 70 | 65 |
| 65 | 60 |
| 65 | 50 |

It will be noticed that the results in the left hand are larger than those in the right-hand column; that is, when A is simply demagnetized by B, it can support a greater weight than when it is employed to magnetize the bar against the resistance of B.

In short, the result of my experiments has been to show that a given helix, traversed by a given current, has more power to demagnetize than to magnetize, while its power to prevent magnetization is greater than either.—*Silliman's American Journal.*

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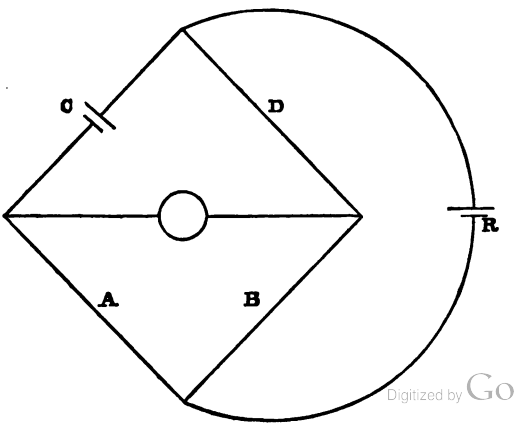
## ON TESTING THE METAL-RESISTANCE OF TELEGRAPH WIRES OR CABLES INFLUENCED BY EARTH-CURRENTS.

By G. K. Winter, Telegraph Engineer, Madras Railway.

The fact, I believe, is sufficiently well known to all who have had anything to do with the testing of telegraph-wires or cables, that it is almost impossible to have two earth-plates inserted any distance apart without a difference of tension, greater or less according to circumstances, existing between them; this is due in some cases to earth-currents properly so called, in others to polarization of the earth-plates from the passage of currents, in others to a difference between the earth-plates themselves or the soil in which they are imbedded, but generally to these causes combined. The important influence of the currents in the wires due to this difference of tension upon the apparent resistance of the wire when tested by the Wheatstone's bridge has not, I fear, been hitherto fully appreciated. In Sabine's 'The Electric Telegraph,' pp. 292 and 293, the author deduces from Kirchhoff's laws the following equations (see the annexed diagram):—

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$$\pm\frac{E'}{E}=\frac{BC-AD}{A(D+R)+B(A+R)}, \quad \ldots\ldots (1)$$

$$C=\frac{AD}{B}\pm\frac{E'}{E}\frac{A(D+R)+B(A+R)}{B}, \quad \ldots (2)$$

in which E is the electromotive force of the testing battery, and E′ the foreign electromotive force in the branch C.

From equation (1) we can tell the ratio between these forces when the resistance of C is known; and from equation (2) the resistance of C is found when the ratio $\frac{E'}{E}$ is known; but as these equations are derived one from the other, we cannot, with these equations alone, eliminate either of the unknowns. The author has omitted to point out that if we take two tests, one with copper to line and the other with zinc to line, and the results obtained be called D and *d*, then

$$\pm\frac{E'}{E}=\frac{BC-AD}{A(D+R)+B(A+R)}, \quad \ldots\ldots (3)$$

$$\mp\frac{E'}{E}=\frac{BC-Ad}{A(d+R)+B(A+R)}, \quad \ldots\ldots (4)$$

the signs before the ratio $\frac{E'}{E}$ being opposite in the two equations, but the decision as to which is *plus* and which *minus* depending upon the direction of the foreign electromotive force, which we shall henceforth call the earth-current.

It follows from this that if we add the two equations together we at once eliminate $\frac{E'}{E}$, and get

$$\frac{BC-AD}{A(D+R)+B(A+R)}+\frac{BC-Ad}{A(d+R)+B(A+R)}=0, \quad \ldots (5)$$

from which C is easily calculated, especially when (as is usually the case in testing line-resistance) A=B. The equation then becomes

$$\frac{C-D}{D+2R+A}+\frac{C-d}{d+2R+A}=0. \quad \ldots\ldots (6)$$

Again, if we omit R (the resistance of the testing battery), we get

$$\frac{C-D}{D+A}+\frac{C-d}{d+A}=0. \quad \ldots\ldots (7)$$

As, however, the battery-resistance is seldom so small as to be neglected, it is generally better to use equation (6).

In Clark and Sabine's 'Electrical Tables and Formulæ,' and in a pamphlet issued to the Indian Government Telegraph Department, is a formula by Schwendler* which, while really identical with equation (5) is much more

* The equation as given by Schwendler is as follows:—

$$x=\frac{bf(a+b)(W'+W'')+b^2(aW'+2W'W''+aW'')}{ab(W'+W'')+2af(a+b)+2a^2b},$$

in which *a* and *b* are the branch resistances, W′ the adjusted resistance with a positive, W″ that with a negative, and *f* the resistance of the testing battery.

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complicated and tedious to solve, owing to the attempt to isolate the unknown quantity in the literal equation, which is, I think, a mistake in this case.

The above correction to the Wheatstone-bridge method of testing line-resistance, however, is only true so long as the ratio $\frac{E'}{E}$ remains constant during the two tests. We have not much fear of the electromotive force of the testing battery changing; but earth-currents are, as a rule, continually varying in strength; for this reason I have always considered the bridge method of testing line-resistance unreliable. There are at least two methods which are much to be preferred. One is Mance's method, given in the Number of this Magazine for April last (p. 314), and the other a modification of Varley's method of testing the internal resistance of a cell by the differential galvanometer. In both these methods the cable or line, together with its two earth-plates, is considered as an electromotor, and its internal resistance is measured.

I need scarcely say that in every method of measuring the internal resistance of an electromotor, unless its electromotive force is known two observations are necessary; and if this force is liable to vary, the more quickly these observations follow each other the greater the chance of accuracy. In the two tests just referred to, the first observation is simply the noting of a deflection, and the second is simply seeing that the deflection does not alter when we press a key in one place and raise a key in the other. In land-lines there is usually no interval between the two observations; but in cables the alteration in the resistance of the circuit causes a sudden difference in the dynamic charge of the cable, and hence a sudden flow through the galvanometer. We have therefore merely to wait till the needle comes to rest before the second observation can be taken. Mance's method was so fully described in the April Number of this Journal that I need not further refer to it; so I will proceed at once to the second method, which is more applicable to measuring the resistance of land-lines.

The instrument I use for the purpose is a double-shunt differential galvanometer having the resistance and magnetic effect of its coils equal. The connexions will be readily understood from fig. 1. C is a thick wire offering comparatively no resistance. The key is first pressed, so that the earth-current flows through only one coil of the galvanometer, and the deflection is either observed, or (what is better) counteracted by a directing magnet, and the index brought to zero; the key is then raised; the current circulates in both coils of the galvanometer, and any resistance that may be opposed to it in the resistance-coils D. If the position of the needle remains unaltered, the resistance in the coils is equal to the resistance of the line. If it is necessary to use shunts, the result is the same, provided the coils are shunted by equal shunts; if, however, the line offers too great a resistance to be measured by the resistance coils, we may shunt a greater portion of the current from the coil B of the galvanometer than from the coil A. Say, for instance, we shunt $\frac{9}{10}$ of the current from A and $\frac{99}{100}$ from B; then the line-resistance will equal the resistance in the coil multiplied by 10. If the earth-current is not sufficient to give satisfactory deflection, we

have merely to insert a battery of known resistance between the line and galvanometer, and subtract its resistance from the result. It is generally indeed better to do so, as in that case the variations in the earth-current will not be so perceptible.

The differential galvanometer I have designed and constructed for the use of my inspectors is well adapted to this test; and as it has proved so useful in practice, I venture to hope a short description of it may not be unacceptable to the readers of this Magazine.

The exterior form of the instrument is somewhat similar to Varley's original universal galvanometer, and is shown in plan in fig. 2, with the connexions in dotted lines.

The two wires of the coil are wound simultaneously and as carefully parallel as possible, so that their magnetic effects may be equal. Their resistances are also made equal. The needle is suspended by a short fibre of silk from a small bracket in the interior of the coil, which bracket slides in and out in a groove.

When it is desired to render the instrument portable, we can, by turning a milled-head on top of the cover, raise the needle and press it firmly against two pieces of cork on the top of the interior of the coil.

The index is fixed at right angles to the needle. The end of the index plays between the two upright sides of a small frame. This frame is attached to an arm which runs under the base of the instrument, and is moveable in a segment of a circle concentric with the point of suspension of the needle. The bottom of the frame is a small brass plate, with a line drawn across it so as to be radial to the circle in which the frame moves. The top of the frame carries two cross wires, which intersect each other in a point exactly over the radial line on the bottom. When a reading is taken, one eye only must be used, and the intersection of the wires, the end of the index, and the radial line on the bottom of the frame must coincide, so that the parallax is avoided. The object of the frame is therefore twofold; first, it serves to limit the vibration of the needle; and, secondly, it gives us a very exact means of noting a deflection. There is a small needle-point attached to the bottom plate, forming a prolongation of the line; and, finally, upon the dial-plate are engraved, instead of a number of degrees or other arbitrary divisions, simply a line at right angles to the coil, to serve as a zero-line, and two radial lines on each side, the use of which we shall presently see.

There is a small socket in the top of the cover of the instrument, immediately over the centre of suspension of the needle, in which may be fixed a rod carrying a directing magnet. In testing ordinary resistance, this magnet may be made to oppose the earth's magnetism, so as to render the needle astatic; or it may be made to counteract a deflection, as in taking battery or line-resistance, as already explained, so as to bring the needle into its most sensitive position; or t may be removed altogether.

Besides all the ordinary tests, to which a deferential galvanometer can be

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applied, we are able with this instrument to measure approximately electromotive force; and for this purpose the radial divisions above referred to are engraved on the dial-plate.

The method is that described by Wheatstone in the Philosophical Transactions in 1843. There are, I should have said before, three shunts to each coil, cutting off respectively $\frac{9}{10}$, $\frac{99}{100}$, and $\frac{999}{1000}$ of the current.

In order to determine the position of the two divisions on the left-hand side, I insert the $\frac{99}{100}$ shunt on each coil; a good ordinary Daniel's cell, such as is commonly used on the line, is then taken and joined up through the galvanometer and resistance-coils, as shown in fig 3. Resistance is then inserted until a convenient deflection is obtained; the frame is then made to coincide with the index, and the position of the needle-point marked on the dial plate; 10 units are then added to the resistance, the deflection is of course reduced, and the frame is made to coincide with the index a second time, and the position of the needle point again marked on the dial. The two points marked have then conspicuous radial lines engraved through them. On the right-hand side we do exactly the same, except that the unit-cell is formed of an amalgamated zinc plate in 1 of sulphuric acid to 12 of water, and a copper plate in a saturated solution of nitrate of copper; the electromotive force of this element being about 1 volt.

When the electromotive force of a cell or battery has to be measured, we join it up through the galvanometer and resistance-coils, making the needle deflect either to the right or left, according as we wish to measure in terms of a volt or of our standard ordinary cell. We then bring the needle-point of the frame to the first of the lines and adjust the resistance until the index coincides with the line and cross wires; we next shift the frame until the needle-point is at the second position, and resistance is added to the circuit until the index agrees a second time with the line and cross wires. The amount of resistance added is a measure of the electromotive force. If the $\frac{99}{100}$ shunts are used, each unit of the added resistance represents one-tenth of the force of the standard cell or the volt, as the case may be. If the $\frac{999}{1000}$ shunts are used, each unit represents the force of one cell or volt. If the $\frac{9}{10}$ shunts are used, each unit represents the one-hundredth of the force of the standard cell or volt; and finally, if no shunt at all is used, each unit represents one thousandth of the force of the standard cell or volt. These measurements are quite sufficiently accurate for ordinary use in testing telegraph-batteries, and are quickly and easily taken.—*Philosophical Magazine.*

Communicated by H. R. Kempe.

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Fig. 1.

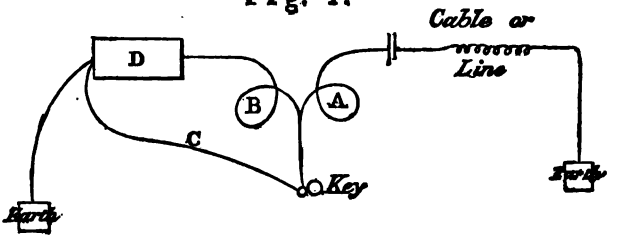
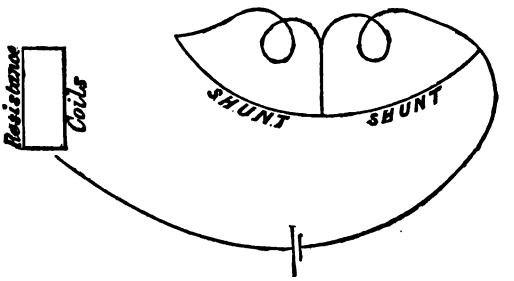
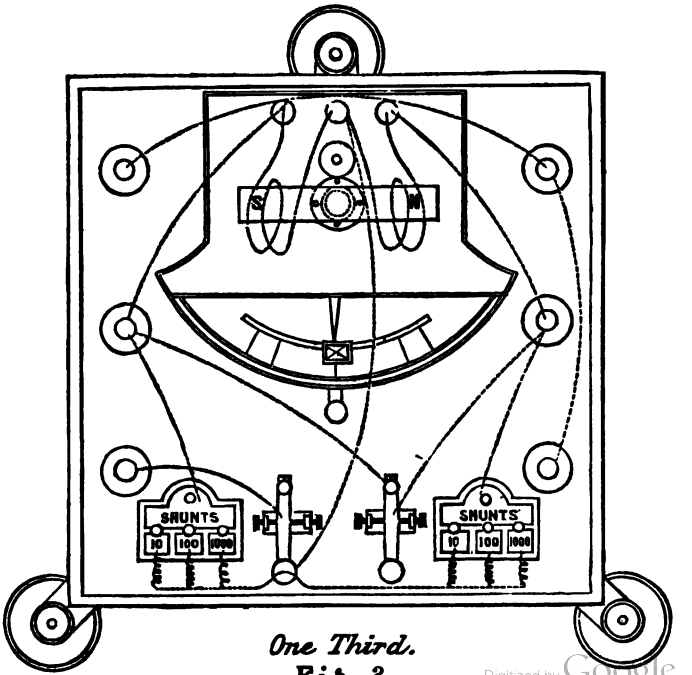



Fig. 3.




One Third.

Fig. 2.

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## ON THE ADVANTAGES OF SCIENTIFIC EDUCATION. A LECTURE ADDRESSED TO THE TELEGRAPH STAFF.

By William Henry Preece.

The object I have in view in lecturing to you this evening is to prepare you for a course of Lectures which is about to be delivered upon the science of Electricity, and to endeavour to induce you to devote more time than you hitherto have to the study of the scientific principles upon which Electric Telegraphy is based.

There is a great difference between an art and a science: an art teaches us *to do*, a science *to know*. The object of science is knowledge; the objects of art are works. In art truth is a means to an end; in science it is the only end. Thus, in our profession, the truths of Electricity and Magnetism have been the means by which the art of Telegraphy has been established.

You are proficients in the art, but deficients in the science. I hear some of you say, "We are proficients in the art, why bother us with the science?" I will show you why.

---

### A.—ITS ADVANTAGES.

#### I.—Pleasure.

The first advantage is—The Pleasure which it affords.—Many natural events—meteorological changes, the aurora borealis, thunder storms—are constantly attracting our attention. Who is there that derives pleasure from reading a book that he does not understand, or is not gratified at the perusal of one he thoroughly understands? Nature is a book to read; its effects are its poetry, and the applications of science are its light literature.

How many a fact has passed beneath the eye of the stone-breaker which the geologist would have given years of his life to have known. So with the botanist and the ordinary labourer in the field. So with the lineman or the operating telegraphist; the effects of earth currents, atmospheric electricity, and of induction, are constantly passing beneath his eyes. He observes much the scientific telegraphist would have given anything to have witnessed. There is a pleasure in tracing effects to their cause, and distinguishing the one from the other. "Contacts," "disconnections," and "earths," are constantly occurring. The mind trained to knowledge follows such effects to their cause at once. The ignorant regards them with the same feeling as the animal which cowers under an hedge during a thunder storm. The one has the excitement of the hunter, and the pleasure of the seeker after truth: the other remains callous and unconcerned.

Who is there that does not feel delight at the acquisition of money? The study of science means the acquisition of fresh ideas. Knowledge is power,

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and ideas are wealth. The study of science is an unfailing source of the highest intellectual enjoyment. It is a mental educator of the highest order. Who does not feel happier who recovers his health, or does not feel invigorated from a change of air? Science is medicine to the mind, fresh air to the understanding. It sharpens our perception, enlarges our views, and opens up a new world to our inspection.

Why is it so little popular? It does not appeal directly to our sense. It involves thought, study, and time. *Thousands* rush to hear a comic song where *one* goes to hear a scientific discourse. People do not like trouble. There is unfortunately no royal road to learning. Knowledge is fixed at the top of a hill, which requires some stiff climbing; hence science is unpopular. There is a great tendency to ridicule that which we do not understand. Fortunately the scientific man has the laugh on his side. He gains much more amusement from the ignorance of the unscientific, than the unscientific, though in the majority, do, from the hard names, queer subjects, and petty minutiæ which apparently monopolise the time of the physicist. Some of our leading writers, and even thinkers, are so ignorant of the common elements of science, that the mistakes they make are simply outrageous. Illustrations of this are not wanting in the works of even the famous Dickens. He has, by strange *lapsus pennæ*, not only made a star a fixture to the earth, but has made the day to be the result of the revolution of the earth around the sun, instead of the rotation of the earth upon its own axis. One of our most celebrated newspaper correspondents has very recently, in describing an early morning walk to Epsom, said:—"The day had gradually dawned—a beautiful, fresh, fragrant morning that gave promise of a charming day. On every green thing there yet lay the heavy dew; *on the dusty road it had been licked up as if it had never fallen.* The pure air was full of the sweet music of singing birds, and from afar off came the double note of the cuckoo." This very pretty passage has been marred by the scientific absurdity implied in the falling dew licked up by the dust. Dew is formed where it is found, like the moisture upon the underside of a glass of ice-cold water.

A scientific man is one who knows—and one who derives pleasure from that which he knows—hence the chief advantage which I lay before you to be gained by the study of the scientific part of your profession is—pleasure.

## II.—Professional Standing and Position.

The second advantage which I hold out as an inducement to you to apply yourselves to science is the improvement that it will effect in your professional position.

Smiles has well remarked that "steady attention to detail lies at the root of human progress." No man can hope to obtain a position of *trust* if he neglect detail. The knowledge of the mechanical portion of your profession is not

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sufficient. Mr. Culley has said, "What would be thought of an engine-driver who stuck on a bank for the want of knowing how to use sand on the rails?" Such, I am sorry to say, is the position of the great majority of those who are employed in the operating branch of our department. The gentleman last named, and I, were recently visiting the terminal station of one of the most important of our long ocean cables, where messages were pouring in, read by the movements of the ray of light reflected by Sir William Thomson's beautiful reflecting galvanometer. That important station is under the charge of one who, many years ago, acted as clerk—and a very indifferent clerk—to Mr. Culley. He has since made great advance in the profession, and now occupies a very responsible position. He said that he never made any progress in the world of telegraphy until he commenced to study electricity; and from the moment that his time was devoted to scientific pursuits his progress was rapid.

It is not difficult to adduce many examples of the advancement those have received who have paid attention to this branch of their profession.

Scientific training is much cultivated on the continent. I do not know that foreign telegraphists are better than English ones, but I do say that English ones with training must come to the front, for that self-reliance, perseverance, energy and presence of mind, which are the distinguishing characteristics of the Anglo-Saxon race, must, with training, place English telegraphists in the front rank.

In America, owing to the difficulties of locomotion, every operator is his own lineman, inspector, and superintendent, combined. All future appointments to the principal post in the British Postal Telegraph system must fall to those who have gained a reputation by their studious habits, observation, and attention to the technical details of their business.

### III.—Pay.

There is no doubt that a knowledge of the technical details of telegraphy will eventually lead to an increase of the emoluments of those who are now engaged in the department. It is intended to establish regular schools at various important stations, to assist those who are anxious to acquire this technical education. This has already been done at Southampton. Indeed, so much is it considered necessary that a certain portion of technical matters should be known by all, that all learners will be required to qualify and receive a certificate of a certain knowledge of the construction and adjustment of the different apparatus they are required to learn. Promotion, also, from one class to another, will be made dependent upon such certificate. In fact, it is proposed that all those in the service shall comprehend, as a portion of their duties, the connections and construction of their instruments; that they shall be able to join up these instruments; and that they shall possess the ability to detect and remove faults in their apparatus and batteries. It is also intended to establish two grades, and that those who enter these grades will be required

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to pass through a certain examination. Bonuses will be given as rewards to those who pass these examinations in proportion to the skill and talent they display. The first grade will include those who, in addition to the knowledge indicated above as being required by them in the ordinary discharge of their duties, can localise faults, understand the construction and use of testing-boxes, tangent, and ordinary galvanometers, and have some knowledge of the elementary principles of electricity and magnetism. The highest grade—in addition to all that precedes—will be required to understand thoroughly the higher classes of apparatus, such as translators, Hughes', Wheatstone's automatic, &c., to use Wheatstone's bridge and resistance coils, and to pass an examination in the principles of electricity and magnetism.

It will thus be seen that means will be afforded to those who desire to improve their position, and that pecuniary advantage must necessarily accrue to such as avail themselves of these opportunities.

## IV.—Education.

It will be admitted by everybody that improvement is desired by all. We must march with the times. Much more attention is now being bestowed to technical education, not only in our department, but in every occupation where science is applied to useful purposes, and you must not be behind those who come after you.

Education is of two kinds—imparted, and acquired, i.e., imparted by the aid of teachers: acquired by one's own industry. All successful men are self-educated, education in reality only commences when we leave school. At school we are simply taught *how* to learn: when we enter the world we commence *to* learn; the higher the position we attain, the more we have to learn. Our leaders are every day in school. The more you work now, the less you will work hereafter. The less you work now, the more you will have to work when you reach those positions of trust and responsibility, which are the ambition of all, and which are open to all. The difficulty of learning increases with age. In youth it is an easy matter to pick up information, and impress it upon the memory. Information acquired during youth is not easily forgotten—or if forgotten, it is very easily recalled. The older we get the more difficulty there is in adding to our stock of knowledge.

The object of education is to attain precision of thought, and to possess the power of drawing correct inferences from facts. Indeed to exercise judgment, and common sense. There is no better method of acquiring these valuable qualities than by a scientific training. We can find out many things without scientific training,—trace faults, etc.; but we can do such things much more quickly, more correctly, and with more gratification, with such training. Rule of thumb methods have always a flavor of science in them, and though it has been said that an ounce of practice is worth a ton of theory, an ounce of practice *with* theory is worth a ton of practice without theory.

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### V.—Invention and Improvement.

The last advantage to which I shall call your attention is this:—Scientific knowledge and training are the parents of invention and improvement, and these are the highest order of education. I do not mean scheming, or the bringing forward of novelties for the sake of novelty, often in opposition to fixed principles; but the improvements of defects and the introduction of objects of real utility. Watt has said "it is a great thing to find out what will not do, it leads to our finding out what will do." When we know where the shoes pinches, we can find a remedy.

Some of the schemes which ignorant outsiders have submitted to telegraph engineers as improvements are simply ridiculous. I can remember, when the Atlantic Cable of 1858 failed, a lady writing and suggesting that cables should not be submarine but supermarine—that they should be suspended above the ocean; and she suggested that the rock of Gibraltar, the peak of Teneriffe, and the Andes formed conspicous objects for this purpose! Again when we suffered so much a little later from the rupture of our light cables in the North Sea, an officer of one of the scientific corps of Her Majesty's army thought that he had made the grand discovery that the world was growing, and that it was owing to the continents separating themselves farther and farther by the growth of the globe that our cables snapped! Many suggested that the Atlantic Cable should be suspended by balloons, and even very recently a gentleman who possesses no knowledge whatever of telegraphy has endeavoured, by the powerful aid of the press and other means, to thrust upon us an apparatus which we know to be radically wrong in principle, and which has been anticipated or tried by nearly every telegraph engineer who has exercised thought on the subject.

On the other hand, those who possess scientific training, and those who have devoted their attention to remedy defects, have done great service to their profession. Mr. Fuller succeeded in replacing the defective sand batteries of 20 years ago by the ordinary sulphate battery, which still remains the form principally employed by the Department. Mr. Varley, by the application of his powerful mind to the working of our wires, has brought the present state of insulation to the perfection it has now attained; and Sir Charles Wheatstone, by the constant and unremitting study of 40 years, has brought out that beautiful automatic apparatus without which it would have been difficult for the Postal Telegraph Department to have transacted the enormous business thrown upon its hands by the adoption of the uniform shilling rate, and the low tariff applied to the press. The two first-named telegraph engineers owe their success entirely to those principles of self-education that I wish to inculcate into you, and Faraday—a purely self-educated philosopher—has instanced Sir Charles Wheatstone and his inventions as examples of the effect of the continued application of these principles.

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There is plenty of room in the working of our instruments and wires for the display of your powers of invention and improvement. Real improvements are not the results of chance. They are the effects of the continued application of those methods of thought and study which education, and particularly scientific education, imparts.

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## B.—SUBJECTS OF STUDY.

Such being the advantages which I offer for your consideration what are to be the subjects of your study? It is, of course, impossible for any-one to acquire all branches of knowledge; it must be divided into departments. No great concern can be managed without distributing its work. The departments of which the telegraphist should know something are mathematics and physics.

### I.—Mathematics: Pure and Applied.

(*a*) *Pure.*—Mathematics is a mere machine or tool which enables us to manipulate and shape thoughts or facts. The hand and the mind each work in their own way, but neither can do much without help. The hand is useless without tools, and the mind without knowledge. Mathematics is one of the mind's most valuable assistants. It only needs interpretation. Its name frightens. The word Mathematics has an alarming sound. Algebra, Trigonometry, and the Differential Calculus are terms that inspire terror into the minds of the uninitiated. But each of these subjects, if energetically grappled with, proves to be so simple that after once the stile has been crossed you look back and smile upon the difficulties which apparently encumbered the path, but chiefly in the imagination. The study of Mathematics instils habits, and teaches methods which are easily transferred to other fields of mental labour. It is in reality a thinking shorthand. No one should be deterred by the letters and symbols which are used to designate mathematical processes, and particularly those who are so used to arbitrary symbols as telegraphists. Geometry and algebra are indeed essential to the skilled telegraphist, and it is difficult for any one to comprehend the higher branches of his profession until he has mastered the elementary principles of those two branches of pure mathematics. It is the application of Algebra which enables the telegraph engineer to tell the distance of a fault in a submarine cable to within half-a-mile, and to direct the sailor with unerring accuracy to the spot where he must apply his repairing apparatus. It is Trigonometry which enables the sailor by the observation of the sun and stars to direct his ship, though in the middle of the ocean and far away from lands, to this very spot. It is the Differential Calculus which enables the electrician to obtain the greatest possible speed of working with the least consumption of materials out of his submarine cable.

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But the chief value of mathematics is the power which it possesses to train the student to habits of thought. Geometry is, in fact, the finest system of logic, the best art of reasoning which the world has ever seen; and in our daily avocations, in the dealing with complaints, in the investigation of errors, in scheming arrangements for the better transaction of our business, we are constantly, but unconsciously, using those particular habits of thought which the art of reasoning, as illustrated in geometry, teaches us to exercise. No knowledge can be depended upon that is not founded upon conviction. This is the chief beauty of algebra and geometry.

(*a*) *Applied.*—The first principles of Dynamics, or the laws of motion, are essential to the thorough conception of the laws of nature. Dynamics considers force, and its measurement. A current of electricity is only one form of force, and all our methods of electrical measurements are based primarily on the laws of dynamics. Dynamics teaches us how to comprehend thoroughly most of the fixed and invariable laws of nature. The stability of our posts, the strains upon our wires, the submersion of our cables, are but applications of the laws of dynamics. The motions of a boat upon the river, of a train upon the railway, and the moon around our earth, of the earth around the sun, and of those numerous bodies that make up the splendid floor of Heaven, are all dependent on the simplest possible laws which are within the apprehension of everyone of my hearers.

## II.—Physics.

Physics deals with heat, light, electricity, magnetism, sound and chemistry. A knowledge of chemistry, magnetism, and electricity, is indispensable to the telegraphist. The study of any one of these sciences lets in a flood of light upon the others. They are so mutually dependent that a little must be acquired of each branch of physics by studying any one of the three I have enumerated. It is impossible to comprehend the internal action of a battery without some knowledge of chemistry. The actions and reactions that there take place produce those dynamical effects which transform energy at one time into electricity, at another time into magnetism, at another time into light, and at another time into heat; for heat, light, magnetism, and electricity are only different forms of that one great, universal, and indestructible agent called *energy*.

Experimental physics is the growth of the present century, and it is a mental training of the highest order. In the study of this subject we exercise and strengthen our powers of observation, memory, judgment, and imagination—faculties which are essential to the advancement of telegraphists. More than this, the study of experimental physics is a fine training ground for the temper. There is no use getting excited over the failure of an experiment. If we fail, we must try again, and we are sure to succeed in the end.

"Nature never did betray
The heart that loved her."

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## C.—AIDS TO STUDY.

The question now rises how are you to obtain this knowledge. My reply is:—

### I.—By Attending Lectures.

It is intended when practicable to deliver courses of lectures upon those subjects which you will be required to know. We are now about to commence such a course; but supposing that you are stationed at a place where this is impossible, it may happen that a local institution is in existence which offers practical facilities to enable you to attain the same end. I beg, therefore, that you will keep a careful watch upon the actions of local institutions, so as not to lose an opportunity of learning from such sources those branches of science which you are desirous of mastering.

### II.—By Reading.

Bacon has said, "Some books are to be tasted; others to be swallowed; and some few to be chewed and digested." The books which I recommend to your notice for chewing and digestion are:—

"Culley's Handbook of Telegraphy;" "Ferguson's Electricity," "Deschanel's Physics" (translated by Everett), "Tyndall on Heat," and the "Science Primers" recently published by Messrs. Macmillan and Company.

A scientific book should not be read lightly, like a novel. Every new fact should be carefully examined, and every fresh proposition thoroughly comprehended. Notes should be freely made as you progress. It is better to know one page of either of the books I have enumerated thoroughly than to have read them all cursorily. The proper way to study a scientific book is first to read a paragraph carefully, to reflect upon it, to see if you have grappled its meaning; then to transcribe it briefly in your own language into your note book. If it describes an experiment, the experiment should be repeated; if it describes an instrument, the instrument should be drawn; if it involves a proposition, the proposition should be proved. Your note book thus becomes a valuable epitome of the subject you are studying.

### III.—By Observation.

Facts should invariably be acquired from actual observation. It is not alone sufficient to read of a fresh fact in a book. An effort should be made to see the fact for itself. Books merely direct search, but one should never be satisfied with mere reading.

### VI.—By Experiment.

Experiment immediately succeeds observation. It is essential that every scientific student become proficient in it. All the elementary principles of the



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science should be impressed on the memory by experimental evidence. Experiment is the language with which nature converses with us An experiment is merely a question asked of nature. The American poet has said :—

> "To him who in the love of Nature holds
> Communion with her visible forms she speaks
> A various language."

The examination of the facts given to the mind by experiment leads us on to theory, which enables us to exert the imagination, not by the lay of mere fancy, but by the force of pure reasoning. Experiment teaches us to comprehend the action of nature, and when aided by theory, and imagination, it enables us to see with the eye of the mind operations and actions that are totally invisible to the eye of the body.

## V.—By Reflection.

A true theory enables us to reflect, explain, and predict. By making an experiment, and reflecting upon it, we are able to grasp phenomena, and trace effects to their cause, in a way that imparts the most pleasurable sensations to the mind. A simple experiment leads to theorizing, theorizing leads to reflection, and reflection suggests variations for further experiment. We predict results, and when subsequent experiments confirms the result, which thus becomes the child of reflection and theory, the pleasure imparted thereby is most intense.

The chief difficulty met with in acquiring scientific knowledge consists not so much in failing to comprehend language as in failing to grasp ideas. It is of little consequence what words we use to express an idea, provided we possess that idea. Words are mere symbols of ideas. For instance, we have in electricity a quality or "function," as it is called, which determines its motion from one point to another, analogous to temperature in heat and pressure in fluids. Some call it *tension*, some call it *intensity*, some call it *potential*. I say call it what you like as long as the word you use recalls the proper idea, and if you always associate the proper idea with the word you have no difficulty in following different authors, though they do use different words to express the same idea. A current of electricity in a wire is due to a difference in the magnitude of this function at its two ends, and if you read that it is due to a difference of tension, or of intensity, or of potential, you will have no difficulty in knowing what is meant when you know that each of these words is intended to express the same idea. It is a misfortune in electrical science that agreement does not exist as to the use of terms, and this want of uniformity adds considerably to the difficulties met with in mastering it. A new Society of Telegraph Engineers has recently been established, which will probably do much good in this direction. There is no mode so effectual to impress ideas on the mind as that of experiment aided by reflection. The fundamental principles of every science must be grasped with clearness before that science can be

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mastered. We must have the clearest notions of the terms, the definitions, the postulates, and the axioms, of a science. First principles must be mastered, everything else then flows on logically. In fact it is simple reasoning, and these first principles can only be imparted by experiment, aided by reflection. The knowledge of technical terms in daily use is essential to the practical mind. It is an invaluable plan to watch workmen when they are at work; to examine their tools, to observe their processes, to learn from them their names and purposes. This is only observation and reflection of another kind. Manufactories should be visited, and all mechanical contrivances for any purpose should be carefully noticed, and form them the food for subsequent reflection.

### VI.—By Noting and Writing.

You should always carry with you a note-book, or pocket-book, in which everything fresh, everything striking, should be at once jotted down, and there secured as food for reflection. You will thus habituate yourselves to the most invaluable method of fixing upon your minds facts which will be of subsequent use to you. Always bear in mind Captain Cuttle's sage remark, "When found make a note of," and never neglect his wise advice. When in reading a book, or in conversation, or in thought, a new idea is brought to your notice, note it down at once in your book for further investigation, either in your library or by experiment, or by enquiry from some experienced person. Unless difficulties are recorded when they are met with, or new ideas seized upon and noted down at once, they are apt to escape the memory altogether. I recommend you very strongly to write your notes neatly and carefully and not to destroy them. If they are written on the same sized paper, and kept together under their proper subjects, they will prove a never-failing source of profit and pleasure.

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## D.—CONCLUSION.

Experience has shewn that the great difficulty to be surmounted by those who desire to acquire knowledge, is the wish which they possess to proceed rapidly. Progress, to be real, must be slow and cautious. Remember if we gain but one fact a day we have 365 facts in the course of a year, and the science of electricity itself is made up of a less number of facts than that. Hence, if we are satisfied with the acquisition of but two facts at a time, and take care to thoroughly grasp them, we shall, by slow and sure progress, speedily acquire the knowledge we desire to possess.

When you witness an extraordinary circumstance, ask yourself "Why is this? Let me investigate, let me test, let me prove." We must begin by doubting and end by proving. Nothing valuable can be honorably gained without observation, and without labour. In proportion to the greatness of

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the difficulty is the smallness of the number of those who succeed. I do not under-rate the difficulties before you in acquiring a knowledge of electricity. In fact, the few who have succeeded is a proof of the proposition.

There are certain aids to your success amongst which I have enumerated books, but much is to be done by mutual assistance in conversation and debate. At Telegraph-street the engineering staff meet frequently, merely for the discussion of scientific facts and opinions, and *much* good is done thereby. Another great aid to success is drawing, and those who have the slightest idea of the use of a pencil should cultivate that accomplishment as much as possible, and never delay committing to paper what they see worth depicting by pencil.

Bacon says, "Studies serve for delight, for ornament, and for ability. Their chief use, for delight is in privateness and retiring, for ornament is in discourse, and for ability is in the judgment and disposition of business." Again he says: "Crafty men contemn studies, simple men admire them, and wise men use them."

I hope I have been addressing simple men who will admire, and wise men who will use them. Success in life is only to be obtained by industry. The scientific principles upon which our art is based are only to be mastered by such methods as I have submitted to you. It is Mr. Scudamore's intention to give you every facility and offer you inducement to become proficients in the science as well as in the art, and if you fail the failure will be due to yourselves alone.

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## METHOD OF INJECTING TELEGRAPH POLES, USED IN NORWAY.

The managers of the Telegraphs in Norway have for some years past successfully employed a simple and cheap process for injecting poles (already erected) in hilly districts. It is founded on the fact that in pines and firs which have been lately cut down, the circulation of the sap still continues. The process consists in drilling in a manner shown below, holes from six to seven inches deep, near the ground, in the sappy parts of newly erected poles, and in such a manner as not to weaken them, and at the same time to cut through a sufficient number of sap-cellules (or ducts). These holes are then filled with a solution of sulphate of copper, or even with solid sulphate of copper which dissolves, spreads to the neighbouring sap-ducts (within a radius of about an inch), and vertically throughout the length of the pole. As the circulation of the sap continues long after the poles are cut down, in consequence of the successive expansion, and contraction of the wood, which goes on for some years, the sulphate of copper soon gets to the summit of the sappy part of the pole, decomposing the albumen on its way.

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Twice or thrice a year for two or three years the sulphate is injected, and the holes plugged with dry plugs or stoppers, about two inches long, smeared with pitch or some other viscous matter, in order to prevent the expansion and contraction of the wood forcing out the plugs.

When the poles which should be newly cut have been erected, the boring is done in the following manner: a chalk mark is made about six or eight inches above the ground, and another a little more than a yard vertically above the first. These two points are joined by a spiral, chalked out on the post, and on the spiral, points about a foot apart are marked. At each of these points, holes from 6 to 7 inches deep are drilled (with an inch or 1½ inch drill), not straight into the heart of the wood, but obliquely, so as only to cut the sappy parts of the wood. When the holes have been made, they are filled (if circumstances permit and in order to hasten matters) once or twice with a concentrated solution of sulphate of copper, and later on with solid sulphate crushed and jammed into the holes, like powder into holes made in rocks for blasting. In favourable circumstances, the sulphate is absorbed in two or three months, and the holes are refilled until about a pound of the sulphate is absorbed, more or less of course according to the size of the pole. Then the holes are plugged. Since 1858, most satisfying results have been obtained in Norway on several new lines. On inspecting the poles after they had been up ten years, very little renewal was found necessary.

Communicated by W. H. Preece.

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## ON AN ELECTRICAL EXPERIMENT WITH AN INSULATED ROOM.

By F. C. Webb, M. Inst. C.E.

Some ten years ago, in a series of Articles in "The Electrician," afterwards published in book-form, I submitted some new views on the explanation of the action which takes place in various well-known electrical phenomena. I endeavoured to prove by reasoning that the ordinary explanations given of the discharge of a charged conductor by communication with the ground were erroneous; and I suggested an experiment with an insulated room as a means of proving the fallacy of these ordinary explanations of discharge, &c. This experiment I performed in May, 1869, at Keyham Dockyard; and I think the results are worth placing on record.

To make the bearing of the experiment intelligible, however, it is necessary to recapitulate a little of what I have before urged.

It is generally stated in books on electricity, that, when an electrical machine has its rubber to earth, on the action of the machine the prime conductor becomes charged positively and the equal quantity of negative electricity which is generated is lost in the earth—and that when the prime conductor is then placed in contact with earth, its discharge is merely the consequence of its

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sharing its electricity with the earth, the proportion remaining on the conductor being, in virtue of the almost infinite size of the earth as compared with the conductor, almost infinitely small, and consequently quite inappreciable.

I will not weary your readers by quoting, but will merely refer them to:—Professor Daniell's "Chemical Philosophy," p. 241; Lardner and Walker, p. 248; De la Rive, vol. i. p. 3; Ganot, translated by Atkinson, p. 536.

When, therefore, the ordinary experiment of charging the prime conductor is performed in an insulated room, according to the theories which I deny, the negative electricity being unable to share itself with the earth, some differences in the effects produced should be attained. The negative electricity, for instance, if it tends to flow to the earth, should influence an electrometer placed in contact and exterior to the room. Again, if the room is connected to the earth during the charging of the prime conductor and is afterwards insulated, the prime conductor, if touched to the room, ought not to be discharged, since it can only share its electricity with the room instead of with the almost indefinitely large surface of the earth.

Now, I argue, that when electricity is produced, at any rate by an artificial means, the negative and positive are not only always produced in equal quantities, but remain each as much in abeyance as the other, and that complete discharge always consists in the recombination of equal quantities of opposite electricity. Thus, when a conductor is charged, say, positively from a plate-machine having the rubber connected to the earth, the negative electricity has no tendency to flow to and distribute itself equally over the earth, but distributes itself principally on the nearest conducting-surfaces to the positively charged surface; and when the surface to which the negative pole is attached entirely bounds the dielectric which separates it from the positively charged surface, the negative electricity is entirely distributed on that surface, none flowing to any other part of the earth. When these are joined by a conductor, discharge occurs through the recombination of the exactly equal quantities of electricity previously produced.

The experiment to which I allude was performed in H. M. Dockyard, Keyham, where I was engaged repairing a part of the Persian-gulf cable which had been thrown overboard from the ship "Calcutta," and recovered and landed under my superintendence. The insulated room was erected in the large glass-covered quadrangle of the dockyard. I intended to make a series of experiments, carefully recording every step. After a few preliminary experiments, however, of which, unfortunately, no record was kept, our regular work had to be suddenly pushed on; and before any series of experiments could be made and recorded, the whole apparatus had to be removed. Thus I am only able to write from memory; but Mr. Herbert Taylor (one of Mr. Latimer Clark's assistants, and a well-known electrician) was associated with me at the time, and performed the experiments with me. I have submitted this article to him, and he endorses it as a correct statement of what occurred.

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The room was about 8 ft. by 9 ft. and about 8 ft. high. The floor was of wood, and the sides of wooden framework covered with calico and with pieces of tinfoil pasted about it to make it a good conductor. It had a door and two windows of wire gauze. A small table was placed in it, and a frictional electrical machine was placed on this. The room was suspended by four double parts of half-inch-round gutta-percha band to a wooden frame, the floor being about 4 ft. from the ground. The gutta percha was covered with paraffin, and the whole room was tested for insulation with five hundred Daniell's elements with a delicate astatic Thomson's reflecting galvanometer, and gave no perceptible loss. A Peltier electrometer was placed on the ground outside, and a wire from the brass knob of this was connected to the gauze of the window. The table was connected with the tinfoil that was pasted about the surfaces of the room, so that when the rubber or prime conductor was connected to the table it was in connection with the sides of the room. Thus arranged, the machine acted to all appearance exactly the same as in an uninsulated room. When the rubber was connected to the table, on turning the glass disk the prime conductor was charged so as to give off sparks the same as when the room was uninsulated, and the conductor was completely discharged when touched to the insulated room. Not the slightest effect was produced on the electrometer, even when sparks were flashing from the prime conductor to the wire gauze of the windows to which the wire from the electrometer was attached. Connecting the room to the earth made no difference. A sphere about a foot in diameter was then charged when the room was insulated, and then handed out by an insulating handle, when the electrometer immediately diverged to about 50°, showing that the outer surface of the room had become negative. On taking the sphere back into the room, the electrometer fell to zero.

These results agree exactly with what I have suggested would occur under such circumstances in my treatise on Electrical Accumulation, published in 1862, and it is impossible to reconcile these results with the explanation of the action that takes place in charging and discharging, as given and republished in most works. Take, for instance, the following from Noad's Student's Text Book:—"Thus, in order to get any development of electricity, there must be either with the rubber or with the prime conductor, electrical communication with the earth as the great natural reservoir of electricity" (p. 29).

This is about the same language as that used by Lardner, De la Rive, Daniell, Gavarret, and later by Deschenelle.

According to the views I have advocated, the accumulation on the prime conductors depends on the resistance of what I have termed the inductive circuit, which, in the case of charging the prime conductor with the rubber connected to surrounding objects, consists simply of the resistance of the dielectric separating the prime conductor from the surrounding objects, and is therefore the same whether the room is connected to earth or not. More complete views on this subject will be found in what I have written before, both in my 'Electrical Accu-

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mulation' and in a paper "On Inductive Circuits, or the Application of Ohm's Law to Problems of Electrostatics," in the *Philosophical Magazine* for May, 1868.

Dr. Ferguson, in his 'Electricity,' seems to have a tendency to discard the older explanations; but at times his explanations appear to me incomplete, so that it is impossiblo to form an opinion as to what his theory is as regards the actions that take place.

The following paragraph, however, appears to me remarkable, as it seems to show a tendency towards the theory which I have advocated:—

"We have hitherto taken no notice of the — E that, for instance, is said to be lost in the ground when glass is charged positively. Now it may be lost, and the — E induced by the glass on surrounding conductors may be new —E induced by it. But it is also possible, *nay, even probable**, *that this* —E *is none other than the* —E *said to be lost.* If this be the case, the ground acts as much on the glass as the glass on the ground; and the action *is precisely the same as in a galvanic circuit*, when the polarization proceeds in opposite ways in two opposite directions, the action of the one strengthening the action of the other."

Here we have stated as probable what I have urged ten years ago, and which I think I have now demonstrated by experiment.

Dr. Ferguson adds, "However, it makes no practical difference, and it is simpler to suppose the insulated body to be the one centre of force."

With this last paragraph I cannot agree, as it will be found that, by considering problems of electrostatics by means of the theory of inductive circuits, many can be solved which cannot be explained by an allusion to the earth as a common reservoir. The experiment with the insulated room is only one of them. I maintain that no electricity is ever lost in the ground or drawn from the ground as a reservoir. All electricity generated, if we consider it as a quantity, is produced in equal quantities, and can only be neutralized by an equal quantity of electricity of the opposite name.

Thus when the sphere in the insulated room experiment was charged positively from the prime conductor, an equal quantity of negative went to the room. When the sphere was taken out of the room, this negative went to the outside of the room at the same time that the external conductors to the room became polarized, so that there remained on external objects a charge of negative opposing the positive on the sphere, and a charge of positive opposing the negative on the external surface of the room. By connecting the sphere to the earth, the sphere's charge and its opposing charge on surrounding objects neutralize each other, leaving the room negative to a positive charge in the earth, which, when touched together, neutralize each other. Or if the sphere is touched to the room, the positive of the sphere neutralizes the negative on the room, the negative and positive charges in surrounding objects at the same

* The italics are mine.—F.C.W.

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time recombining also. Or when the sphere was taken back into the room, the negative returned to the inside of the room, the positive and negative which were induced on external conductors by the sphere and room when the sphere was external to the room recombining.

It is to be regretted that circumstances prevented me, as I have stated, from performing a regular series of experiments with the insulated room; nevertheless, as the experiment requires space and apparatus not always attainable, I have thought that the experiments, even so far as they went, are worthy of record, even if they do not carry the conviction which my arguments have for so long failed to establish amongst the authors of our text-books on electricity.—*Philosophical Magazine.*

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## ON THE ELECTRIC CURRENTS OBTAINED BY FLEXURE OF METALS.

By P. Volpicelli.

The least bending of a metallic length gives rise to an electric current, when that length forms part of a closed circuit. This was for the first time shewn by Peltier, and the result of his experiments was confirmed by M. A. de la Rive. Peltier made a large circle with a copper wire, which he put in communication with a galvanometer in a short length of circuit, and remarked that in whichever way he curved the wire forming his circle an electric current was produced, which could not be attributed to the magnetic influence of the earth. We shall see, however, that in certain instances these currents are influenced by terrestrial magentism. Peltier also observed that simply rubbing the copper wire with the fingers or with a piece of cloth, produced electric currents. But that it must be remarked that in these latter experiments calorific action is the principal cause of the current, for it can likewise be produced by holding the wire tightly between the fingers without any friction. As to the direction of the currents, Peltier made no observation.

I have followed up the research of M. Peltier, making use of a reflecting galvanometer, and am enabled to add the following facts to those which have been hitherto recorded.

1. Currents produced by flexure are not only obtained with copper, but with all metals; but, other conditions equal, copper produces a greater effect upon the astatic needle than do other metals. These currents also present a very remarkable feature in the total conversion of *vis viva* into electricity, as is the case when lead is used—a metal altogether devoid of elasticity.

2. It is not necessary to use a great length of wire for very sensible flexure currents to be produced; the length of one decimeter is sufficient.

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3. In uniting the rheophores of the galvanometer, however short they may be, the slightest flexure gives rise to a sensible deflection of the needle. It follows therefore that in experiments of this nature, the rheophores ought not to be subject to any strain. This precaution is absolutely necessary, in order to obtain exact results.

4. Flexure currents do not sensibly depend on the development of heat during the flexion of the metal, for when the bending ceases the current ceases also. But, if the flexures are repeated frequently at very short intervals, thermo-electric currents begin to manifest themselves.

5. Flexure currents are so feeble that they are not appreciable to fine wire galvanometers, and in this they resemble thermo-electric currents.

6. If the flexion is produced by drawing apart the two sides of the metallic circuit, a current is obtained, opposite in direction but the same in intensity, as that produced when the same sides are made to approach each other. The former I call the "opening current," the latter the "closing current."

7. The direction of the flexure current in the galvanometer is not changed by reversal of the ends of the metallic length. If even the molecular aggregation of a part of the metallic circuit be altered, reversal of the ends produces no change in the direction of the current produced by flexure. A metallic length with a number of zigzag folds in it, of which a few only had been hammered, furnished a current always the same in direction, although the extremities were reversed; that is to say, that the direction, independently of the reversal above indicated, is in one direction when the extremities are drawn apart, and in the opposite direction when they are brought together. These facts demonstrate that the direction of flexure currents does not to any sensible degree depend on the difference of homogeneousness of the same metallic length.

I ought to observe that I have obtained thermo-electric currents from water and mercury in a closed glass cylinder heated in the middle by a spirit lamp. In this case, also, though I reversed the ends of the cylinder, the current preserved the same direction.

8. If the flexure of any metallic length whatever is so executed that the rheophores to which it is attached move in a horizontal plane, a current is produced which varies in intensity according to the nature of the metal, but which, other conditions being equal, is equally intense at all points of the same plane. This is as true for opening as for closing flexures, and whatever may be the length of the metal employed. But if the rheophores turn in a vertical plane when the flexure is made, then the flexure current falls under the influence of terrestrial magnetism. In the second case the current passes by a minimum, which is nil, as much to the north as to the south of the magnetic meridian; therefore the effect due to this influence comes from a maximum. The current, on the contrary, is at a maximum, whether it be east or west Thus the magnetic influence is a minimum when the currents are directed east and west. The extreme sensibility of the reflecting astatic needle prevents any

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research into vertical flexure currents when there are magnetic perturbations of the earth.

9. One of the means of determining the direction of the flexure currents is as follows:—The experimenter so places himself that he has in front of him the metallic length, the galvanometer, and the scale upon which the image of the index is reflected. Let us suppose also that the rheophores which leave the galvanometer, and are attached to the metallic length to be joined, but do not intersect each other. Thus placed, when flexures are made in a horizontal plane the "opening current" is from left to right of the experimenter, whilst the "closing current" is from right to left. It should be observed that in the "opening current" the metallic molecules are drawn apart the one from the other at the concavity of the metal, whilst at the convex side they tend to approach each other, and that the contrary is the case with closing currents. Perhaps the opposite directions of the currents which have been indicated arises from the inverse alterations of the molecular equilibrium.

10. Equal metallic lengths superposed the one on the other engender a flexure current of less intensity than that which is produced by a single length.

11. If a metallic length, folded into a zigzag with uniform plies, is seized exactly by the middle and pulled horizontally, it produces no deviation on the needle. If the same length without any folds be held by its centre and pulled, a very sensible deviation of the needle is produced. I explain this by observing that in the first case the sinuosities opened at the same time that the two ends of the same lengths were brought together. The contrary flexures produced contrary currents, which neutralised each other.

12. By augmenting or diminishing the quickness of the flexures, one can augment or diminish the intensity of the current.

13. Other circumstances being equal, the augmentation of the number of folds in the length of the circuit diminishes the intensity of the flexure current, which is at a maximum when there are no plies.

14. A metal wire stretched horizontally between the rheophores produces a current when it is drawn from its position of equilibrium, but if it is allowed to return to the same position, a current in the opposite direction is produced. If the wire is then struck and made to vibrate rapidly, so as to produce a sound, the needle does not diverge, for then the rapidly succeeding currents neutralise each other.

15. From paragraph 8, I conceive it may be concluded from the case when the flexure was produced in a vertical plane, that in proceeding regularly in successive planes from north to east, the intensity of the current, at first *nil*, goes on augmenting, and as it passes from east to south, it is always diminishing until it becomes again *nil*. From south to west it augments, and from west to north it diminishes, until it is again nothing. Magnetised steel forms no exception to this law.

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16. Flexure in a horizontal plane, in whatever manner produced, causes in the galvanometer a current, the direction of which is always opposite to that which is produced by flexure, in a vertical plane to the east, but in the same direction as that which is caused when the vertical flexure is to the west.

17. A metallic length formed of different metals soldered together produces a flexure current, which is less intense than that which occur under like conditions, when the length is of one metal only.—*Mechanics' Magazine.*

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## AMERICAN COMPOUND TELEGRAPH WIRE.

In a recent article on the telegraphs in America and the United States, we took occasion to refer to the introduction of a new kind of line wire, known as the "American Compound Wire," its advantages being increased conductivity and strength of material, with decreased weight. The following are some particulars connected with the introduction, manufacture, use, and advantages of this material.

Little or no improvement has taken place in the line wire generally used, except that a larger size has been adopted for greater distances, iron being invariably the material employed; the only copper wire in use in America was taken down so far back as 1846, between Philadelphia and Baltimore, an iron wire being substituted in its place.

No. 9 galvanized iron wire is the favourite American gauge, but in many cases where increased conductivity has been required, Nos. 7 and 8 have been used, and in some cases No. 6 also, but this size is generally considered too large, although we have here many circuits where wire as large as No. 4 gauge is adopted. It is stated that "the strain upon the poles and insulators, the increased number of joints, and the difficulty of making them, as well as the cost of handling and transportation, increase in a rapid ratio with the enlargement of the wire, so that the use of an iron conductor larger than No. 6 or No. 7 is in point of fact almost impracticable." We have found in this country the difficulties mentioned; but the fact that we have many important circuits of entirely No. 4 wire proves that the American conclusion is incorrect.

Mr. Moses G. Farmer, well known in American telegraph circles, conceived early the idea of improving the conductivity of the line wires, and finally, with the assistance of Mr. George Milliken, of Boston, developed the notion of a combination of iron and copper, so that whilst the conductivity of the line should be improved, greater strength and lightness of material might also be obtained. The first form of conductor was a core of steel enveloped in a sheathing of pure copper, but after many experiments a better and more permanent form of wire was adopted. Many attempts having been made before the final and successful plan was introduced

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The manufacture of this wire is now carried on by a company in New York, where extensive works have been erected. The material employed for the core consists of rods of the best cast steel, specially obtained from Sheffield for the purpose; these are drawn down by several processes to the required size; this operation involves a great deal of care and labour, as the wire requires cleansing, annealing, and frequent drawing to reduce it; and when this is completed the wire is again selected, and the ends tested, after which it is cleansed in a solution of sulphuric acid, and then taken to the tinning room.

The operation of tinning is carried on with great care to prevent rust or foreign matter of any kind adhering to the wire; for this purpose it passes through lime water in which it is kept submerged before going through the bath of molten tin. Having undergone this process, the wire is then in a fit state for its copper envelope. The quality of the copper used undergoes the most careful electrical test, none being employed but the best Lake Superior, which gives a specific conductivity of almost absolutely pure copper. The metal is prepared in long ribbons, which are coiled upon reels, and placed in the covering machine, through the centre of which the steel wire passes, and as it advances the reel of copper revolves round, the ribbon covers the wire helically, and by the special contrivances attached to the machine so perfectly that it is almost impossible to detect the joint.

The final stage consists of a second tinning process; the wire again passes through a bath of molten tin, by which process the whole mass is "sweated," as it is termed, into a solid wire, and by the same operation the copper is caused to adhere firmly to the steel core.

The wire is then packed up ready for sale, in bundles ranging from 1 mile to 1½ miles in length, according to the size, and consequently the weight, about three lengths being required for a bundle of 1 mile; these lengths are connected by a special form of joint.

The advantages which are claimed for this kind of wire are, greater durability, increased tensile strength economy in construction and in repairs. Weight per weight being the same, the conductivity of the compound wire is relatively very much higher, but it is usually manufactured in sizes equivalent in conductivity to that of the ordinary line wires in use, so that in making comparisons as to relative cost, &c., the conductivity of each wire would be taken as equal. There is a large quantity of wire of this kind in use in America, but the length of time it has been erected is not sufficiently long for a proper test of durability; the wire, however, remains in a perfect state, and no sign of deterioration has taken place. Some experiments were tried so as to give some crucial tests, and whilst ordinary wire was rapidly destroyed, but little or no effect was observed in the compound wire. The following experiment was devised to try the relative merits of the durability of both simple and compound forms: a wooden box or tunnel was prepared, with a frame arranged in such a manner that wires could be stretched across its mouth like the bars of

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a grating. These wires consisted of various kinds, and were ranged of various sizes, from No. 9 to No. 5 of compound wire guage, and No. 9 to No. 6 of ordinary wire guage; they were placed in such positions that all, whether compound or ordinary galvanised wire, were served alike. A continuous current of steam and air, at a pressure of 80 lb. per square inch, was continually blown through this tunnel night and day, and in addition it was so arranged that at will salt spray could be carried through with the steam and air. The iron wires began to show oxidation about the third and fourth day, and appeared daily to deteriorate; on the ninth day a portion of No. 9 iron wire had been destroyed, whilst the others had suffered considerable damage. On the twelfth day the experiment was discontinued. The result of the trial as regards the compound wire would appear to have been most conclusive, as it remained, irrespective of its size, in excellent condition.

As regards its tensile strength, it would appear to be greatly superior to iron wire of the same conductivity, and consequently for this reason, and its elasticity, larger spans can be employed, requiring fewer poles to the mile. It is therefore much used in river crossings, where frequently large spans are necessary. Mr. Farmer informs us that "some stretches of 1,000, 2,000, and even more than 3,000 ft. are in use, and stand up well, a sample which I lately tested, 120 lb. of steel and 80 of copper per statute mile, had only 9.38 ohms mileage resistance, and broke at 1,051 lb."

As regards the reduced cost of construction we extract the following from an American source, giving the prices of last year, the comparison would, however, hold good at the present time.

Cost of construction with compound wire :—

| | Dol. c. |
|---|---|
| Twelve poles set with insulators .. .. .. | 36 00 |
| One mile No. 7 compound wire .. .. .. | 69 00 |
| Total per mile .. .. .. .. | 105 00 |

Ordinary galvanised iron wire :—

| | Dol. c. |
|---|---|
| Thirty-five poles set with insulators .. .. .. | 105 00 |
| One mile No. 7 galvanised iron wire .. .. .. | 32 27 |
| | 137 27 |

This shows a large gain from the American point of view, but it must be noted that the gain is indirect, the wire being very much more expensive than ordinary wire. Whilst offering only the same conductivity, the gain is obtained from the greater lightness and strength of the material, requiring fewer posts, and less labor. This is the case in an open straight line, but when the route is curved and anything but open, the economy is reduced, and under certain circumstances the employment of the compound wire may in the first place be more expensive, than the use of ordinary wire. It will be seen that as the number of poles in the two cases more nearly assimilate to each other, so must the cost in the same degree become more equal.

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The following are the special advantages which the manufacturers of the compound wire claim for it.

"Economy in construction and reconstruction of lines." If the first be admitted the second advantage must necessarily follow, but it will be seen, as we have stated above, that this economy only extends to such lines where it is possible to reduce the number of poles below that point where the cost in both cases would be equal. Where it is possible to erect a straight line, and that is generally the case in the United States, there is evident economy, and consequent economy in maintenance and reconstruction.

"Economy in transportation of iron and material." If the first advantage be admitted by setting up a line of a minimum number of poles, the reduced cost of transport of material is self-evident. Where, however, the number of poles to the mile differs but slightly, the advantage is slight, being due only to the difference in weight of the wires; this, however, in a country where there are no railways, nor roads, becomes a matter of serious importance and of great advantage.

"Diminution in escape of the electric current," If the number of poles be reduced, this must necessarily follow.

"Superior conductivity." If taken weight per weight this is undoubtedly the case, but then we lose all the advantages we have been referring to, and if, on the other hand, we preserve these advantages, we must necessarily reduce the weight and get at once the same conductivity, so that this advantage is purely conditional.

Lines have been in operation in America since 1868 with this wire, and at the present time there are some thousand of miles (about 4,000) in use in the States, and they appear to give every satisfaction. It may well be asked, if this be an improvement in telegraphy, why have we not used it? It is impossible to tell why; we are not, it is to be supposed, quite satisfied with the material. A small quantity of wire was tried, but the experiments were valueless, though if the material be really good and of any advantage, some definite experiments ought to be made, as there are circumstances under which the adoption of this wire might be of use, especially in long spans in towns over houses.

That there is any probability of its coming into extensive use in this country, we do not for one moment imagine, the high price of the wire and the impossibility of reducing our poles below a certain number, would render the work so costly, as to be at once impracticable.

In very long circuits it has been found advantageous to use a wire of very much larger size, No. 4 guage being used for No. 8, the ordinary guage. It might be asked if this compound wire really possesses all the benefits claimed for it, why not use, instead of the No. 8 wire, a compound wire equal in weight, but necessarily of greatly increased conductivity.

The trials and experiments made with the wire, the amount of wire already

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erected, are sufficient to prove that there are some advantages, some good features in the compound wire; and if its durability, which appears unquestionable, be admitted, it necessarily follows that the wire must possess many excellent points, its principal one being evidently in the erection of a straight line through a country where transport is difficult; the Australian overland line represents such a case. The whole of the material for the line, 1,800 miles in length, had to be transported by sea and by road, the majority by way of the open country where roads had to be made. What an advantage there must have been in such a case in an enormous reduction of the weight of material!

The following are the differences in weight of the compound wire and of the ordinary galvanised iron wire.

| No. | Compound wire. lb. per mile. | Galvanised wire. lb. per mile. |
|---|---|---|
| 9 | 100 | 303 |
| 8 | 113 | 376 |
| 7 | 132 | 448 |
| 6 | 145 | 570 |
| 5 | 160 | 670 |

The manufacture of this wire is being steadily progressed with, and it appears, as we have said, to have a ready use in the United States, where it has met the approval of so many of the different telegraph engineers of the country.—*Engineering*.

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## GRAMME'S CONTINUOUS CURRENT MAGNETO-ELECTRIC MACHINE.

In all the magneto-electric machines hitherto constructed, only an approximation to a continuous current has been arrived at, and that either by making each machine a compound one, and having several armatures arranged so that when the current ceased in one it was taken up by the next, and so on, or in other machines by driving the armature or armatures at a very high velocity, so that the interval between the cessation of one current and the commencement of the next became inappreciable. In M. Gramme's machine the current, whether the Machine be turned slowly or quickly, is continuous. Fig. 1 is a theoretical representation of this machine. It consists of a horse-shoe magnet, N S, between the poles of which turns an iron ring with an insulated wire wound round it in one continuous length. The inner bends of the turns of this wire are connected with small studs *s s s s* insulated from one another. The

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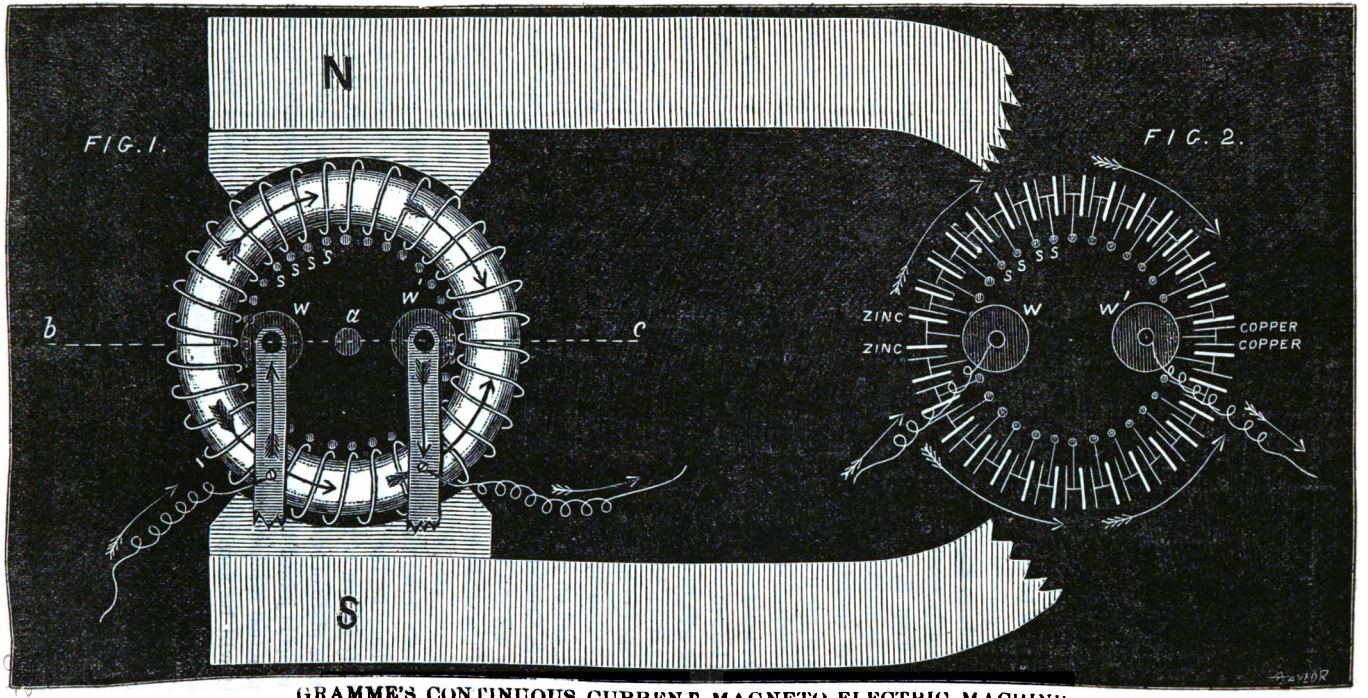


GRAMME'S CONTINUOUS CURRENT MAGNETO-ELECTRIC MACHINE.

edge of the faces of the two wheels $w$ $w'$ press against these studs as shown, so that as the iron ring with the wire wound round it rotates, three or more of these studs are always in contact with them. In the actual machines, each of the turns, as represented in the cut, is really a separate coil of several turns of wire, the junctions between the ends of one wire and the next being connected with the studs, and the iron ring is not necessarily one of round iron, but may be, or rather is, a short and very thick soft-iron tube, and the permanent magnet a proportionately broad compound one The action of the machine may be explained as follows :—Let us regard the turn of wire just above the line $b$ $a$ $c$, on the left-hand side of the ring. The portion of the iron ring above this turn, that is to say, the portion nearest the pole N. has the same polarity as that pole, whilst the portion of the ring below the turn has southern polarity. Now as the ring rotates about $a$, the portion of the ring above the line $b$ $a$ $c$ becomes more strongly north as it approaches N, and the part below less south as it recedes from S, and finally, when it arrives at N, the polarity is the same, which is as much as to say there is no magnetism in it. The change causes a current of electricity to be induced in the wire. As the turn now moves on towards S, the iron in front becomes a south pole, and that behind a north pole, until it arrives at the line $b$ $a$ $c$, when the difference of polarity is greatest. This change sends another current through the wire which, as the turn has become turned over in position, will be in the same direction as the former one, or rather will be a continuation of the first current, so that the turn of wire in changing from $b$ to $c$ has a continuous current induced in it, as have in like manner all the turns before and after it. As now the turn moves further still, the magnetism becomes less and less, as at first, and finally when at S, disappears, and on going still further, becomes reversed as before; this causes a current to circulate through it in a reverse direction to the former one, and so also for all the turns before and after it; these currents together pass out through the studs, in contact with the wheel $w$, and returns when the circuit between the two wheels is completed (as they must be, of course, before any current can flow) through the wheel $w^7$, and thus a continuous current is kept up as long as the wheel is kept rotating. The circuits of the machine are precisely similar to two sets of cells joined up for quantity, that is to say, the last zinc plate of one set joined to the last zinc of the other set, and also the last coppers joined together, as shown fig. 2, each cell representing one turn, or in the actual machine one separate coil.

It will be seen that as each wheel always presses against three or more studs, the coils between those studs are short circuited, and do not add their power to the others. The resistance of the wire in the machine will be the resistance of the length of wire between the stud pressing against the higher part of the wheel $w$ and the stud pressing against the higher part of the wheel $w^7$, taken parallel with the length of wire between the studs pressing against the lower parts of the wheels, which is equivalent to rather less than a

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quarter of the resistance of all the wire taken in one length. The resistance is not exactly a quarter, because the coils between the studs pressing on the wheels are in short circuit, and do not add their resistance to the other wire. By constructing the coils of thick wire, a current of great quantity can be obtained, or with a larger length of thin wire, one of great intensity. The electro-motive force of the current is directly proportional to the rate of rotation of the coils—that is, when the rotation is not extremely rapid, for the demagnetisation of the iron requires a certain time. The machine, from its great simplicity, is likely to have an extended use for such purposes as electrotyping, the electric light, &c.—*Mechanics' Magazine.*

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## ON THE USE OF ELECTRO-MAGNETIC INSTEAD OF ELECTRO-STATIC INDUCTION IN CABLE SIGNALLING.

By G. K. Winter, F.R.A.S., Telegraph Engineer, Madras Railway.

*Read at the Meeting of the British Association, Brighton*, 1872.

There can be no doubt that the commercial success of the submarine cables that at the present time well nigh encircle the Globe, is in a great measure due to the method of working by means of the condenser, invented by Mr. C. F. Varley, and patented by him in 1862.

About two years ago, I thought I had invented a new method of signalling, which, by causing the rise and fall of the strength of current to give signals to the receiving instrument instead of using the direct action of the current, would almost entirely obviate the embarrassments caused by induction and earth currents. I was unaware how completely my idea had been anticipated by Mr. Varley until after my return to England, a few weeks ago, when I had an opportunity of reading the specification of the above-mentioned patent, an advantage my long residence in India had previously denied me. The great success I met with, however, in an actual trial of the method I had re-invented, induces me to hope that a short description of my experiments and their results may be of some value, especially since, as far as I am aware, the method was merely suggested by Mr. Varley, as being possible, and never before, to my knowledge, submitted to the trial it deserved.



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*The currents from the cable were made to pass through a long, fine, primary wire, of an induction coil, and the induced currents in the secondary wire were made use of to work the mirror galvanometer or other receiving instrument.*

In the rather rough instrument, with which my experiments were made, the core consisted of a soft iron rod, 1½ in. in diameter, and 2 ft in length; primary coil consisted of two parallel No. 35 silk covered copper wires, its resistance being about 2500 B.A. units; the secondary coil consisted of two parallel No. 14 copper wires covered with cotton, the resistance being 2·5 B.A. units. The galvanometer was an ordinary Thomson, with a moderately thick fibre, and a resistance about equal to that of the secondary coil.

Through the kindness and assistance of the Electrician and Superintendents of the Singapore and Madras Cable, I was able to try the apparatus on that line. The experiment was exceedingly successful, as many as 15 words per minute being read without much difficulty. The signals were similar in character to those with the condenser, but the elements of the letters were more distinct from each other, and the vibrations, which on one of the occasions were very annoying with the ordinary method, entirely disappeared when the induction coil was in circuit. I should explain that the Singapore Cable is about 1,800 knots in length, and has a resistance of about 10 B.A. units per knot, and a total capacity of about 623 micro-farads.

My first experiments were made with a view of obtaining a simple recording instrument for long cables, and for this purpose endeavoured to work a delicate relay by the induced currents, the relay tongue being so adjusted as to remain against either contact point until forced against the other. On land lines and short submarine cables this is quite possible, but on long cables, unless we use a very large battery power, the rise and fall of the current is not rapid enough to generate secondary currents of sufficient strength to work a relay. A very few words will explain my original idea.

If a series of discontinuous currents be sent in at one end of a cable, the curve of the arriving current at the other end will be such, that for a time approximately equal to the duration of the battery contact at the sending end, the received current will be rising in strength; and for a time approximately equal to the suspension of the battery contact, the received current will be falling in strength.* Now if this received current be made to pass through the primary wire of an induction coil, the induced currents in the secondary coil will be in one direction during the increase of the cable current, and in the reverse direction during its fall; we thus have, say, plus induced currents, corresponding with the battery contacts at the sending end, and minus induced currents, corresponding with the intervals or spaces. The strength of these induced currents will be much increased if reversals are used at the sending end for the spaces, instead of a simple suspension of the current. If these induced currents are strong enough to work a relay we at once get a recording

* See note at page

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apparatus able to print the Morse character, free from the embarrassments due to induction; and as far as the earth currents are concerned, they change in strength and direction too slowly to cause induced currents of any consequence in the secondary circuit. Failing however to obtain a relay, sufficiently sensitive to work with the feeble induced currents obtained when a sending battery of 20 cells was used on the Singapore cable, I tried the mirror as a receiving instrument, and the manipulator being the same as that in ordinary use, I succeeded perfectly.

One great advantage this method possesses over that with the condenser, is, that during the prevalence of the intense earth currents, which accompany magnetic storms, the cable would be only dynamically, instead of statically, charged by them, and hence there is much less danger of damage to the insulator.

I append an extract from a letter from the clerk in charge of the Madras Office, and have merely to add in conclusion, that I shall be fully compensated for the trouble I have taken in the matter if by thus making public the results of my experiments, I contribute in any degree to the advancement of science or the success of telegraphic enterprise.

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## APPENDIX.

### EXTRACT FROM A LETTER FROM MR. J. A. GOTT, CLERK IN CHARGE, MADRAS OFFICE, B.I.E. TELEGRAPH CO.

Madras,
April 28th, 1872.

C. W. Lundy, Esq.

I was at the instrument when Mr. Winter's Apparatus and Mirror Galvanometer were in circuit for two or three hours on the afternoon of the 19th instant.

I observed that the beats on each side were very distinct, and every letter was distinctly formed, and that the slightest pause between the letters brought the light back to zero. A number of messages were received without our having to ask for a single repetition.

(Signed) J. A. GOTT,
Clerk in Charge.

P.S.—I may say that all those clerks who have had an opportunity of reading by Mr. Winter's system much prefer it to the old one.

J. A. G.

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ENDORSEMENT BY C. W. LUNDY, Esq.

DEAR WINTER,

I can fully confirm these statements, having been present at all the experiments.

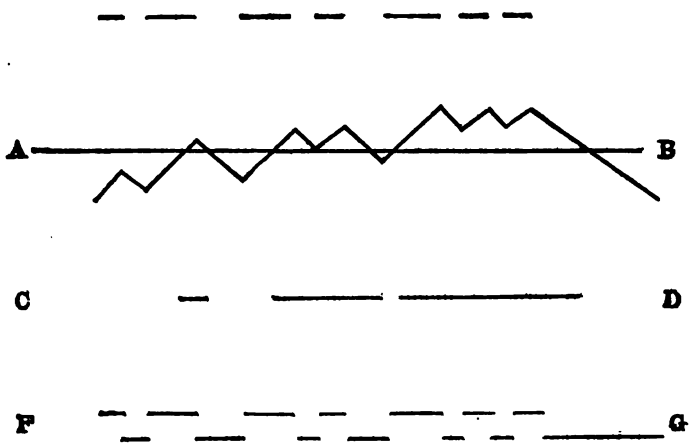
(Signed) CHAS. W. LUNDY,
Madras,
Supt. B. I. E. Telegraph Co.

NOTE.

* The following illustration of the application of the induction coil for use with a polarized relay and Morse instrument will make the explanation of the principle more intelligible.

Let us suppose the dots and dashes at the top of the figure to represent the duration of the battery contacts at the sending end of a cable, then the curved line underneath will represent the corresponding current received at the other end. It is at once evident that no relay, however sensitive, or however adjusted, would render these signals intelligible; supposing, for instance, it were so adjusted as to complete the local circuit whenever the strength of the current rose above that represented by the line A B, then the signals that would be indicated on the Morse instrument are shown in the broken line C D; and with any other adjustment, the signals indicated by the relay would be equally unlike the original signals, and equally unintelligible.

If, however, the received current, instead of being made to act directly on the relay, were made to pass through the primary wire of an induction coil, it would give rise to induced currents in the secondary coil, which would be in one direction during increase of the cable current, and in the reverse direction during its decrease in strength. Indeed currents thus produced are represented




in the double broken line, F G; the upper row representing the currents in

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one direction, due to the increase in the strength of the received current, and the lower row representing those in the reverse direction, due to the decreases in the strength of the received current.

It is at once evident, that a polarized relay, acted upon by these induced currents, and so connected up, as to complete the local circuit when the current acting upon it was in the direction represented by the upper of the two rows F G, would faithfully indicate the signals sent at the sending end, the currents in the reverse direction throwing the relay tongue back, and causing spaces.

G. K. WINTER.

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## A SCIENTIFIC SOIREE.

A telegraphic evening with a little music—pleasantly blending art with science—was enjoyed yesterday by the promenaders in the Royal Albert Hall. Promenading, indeed, was suspended what time General Scott addressed the large gathering, and bespoke their encouraging attention and applause for the lecturer, Mr. William Preece; and also during the historical sketch of electric telegraphy which was given by this distinguished authority. The arena contained about twenty red-covered tables, on which were set forth all kinds of electric apparatus; and the whole interior of the vast building may be said to have been charged with electricity, messages being interchanged between floor and gallery at frequent intervals during the evening. An electric light in the middle of the arena was directed hither and thither at the lecturer's command; the stream of radiance serving to point out, as well as to illuminate, any and every object to which he desired to call attention. For this reason, he somewhat fancifully called the broad luminous beam his "electric wand." Mr. Preece's lecture was of the interesting and anecdotal rather than the deeply scientific kind. He showed, for instance, the "fossil telegraphy" of 1837, holding in his hand the primitive instrument which was first invented by Cooke and Wheatstone. Then he pointed with his "wand," or stream of blue-white light, to the veritable instrument which was employed in the arrest of Tawell the murderer; and he amused his audience by mentioning that, among the missing letters in this machine's imperfect alphabet was the letter Q; consequently when the telegraphing clerk had to describe Tawell's dress as that of a Quaker, he had to spell the sectarian name "Kwaker," which naturally caused a little confusion. The growth of commercial telegraphy dates from 1846; and at that time messages were charged at the rate of 6d. a word. Of course the improvements in the art of telegraphing were attended with great strides in the popular use of the wires, and the figures quoted by Mr. Preece were as entertaining as this kind of statistics is usually found to be. But the most immediately interesting of his facts related to the changes that have followed

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the transfer of telegraphic business from the hands of companies to those of the Government; and both from Mr. Preece and General Scott graceful and appropriate tributes of praise proceeded to Mr. Scudamore, who was present.

Before the lecture was concluded, messages were interchanged between one of the tables in the arena and Teheren, as well as with an Indian station, from which came the intelligence, "Locusts swarming in Scinde; Sutlej bridge destroyed by floods." A message of compliment and congratulation, addressed to the Prince of Wales, was also received from the Persian Prime Minister, in return for one of a like kind sent from the Albert Hall. When the speaking was over, and a vote of thanks to Mr. Preece had been passed, on the motion of General Scott, the company dispersed about the building and the conservatory of the Horticultural Society. Mr. Varley showed, in the arena of the hall, his mammoth battery of a thousand cells; and a torpedo, or something mildly representative of that instrument of war, was exploded by an electric current. The effects of Mr. Varley's battery, with which he charged some large tinfoil condensers, were more like those of frictional than galvanic electricity. The condensers when discharged, gave a sharp report and brilliant spark; and the intensity of the discharge was so great that it blew short lengths of the very indestructible metal, platinum, into a fine cloud of metallic steam. Altogether, the evening was one of the most instructive ever devised in connection with relaxation and amusement.—*Daily Telegraph*, June 19th, 1872.

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## TELEGRAPHY AT THE ALBERT HALL.

The Commissioners of the Albert Hall, under the auspices of the Society of Telegraph Engineers and with the necessary aid readily afforded by the Postal Telegraph Department, provided for the public on Thursday evening, at the Albert Hall, an interesting and striking entertainment. A model of every kind of Telegraph instrument which has been generally used for commercial purposes from the opening of telegraphs to the present time was exhibited. Each apparatus was connected up with wires proceeding from the central hall to the galleries, and thus the actual practical working of the telegraph system was made apparent to those present in a very effective manner. By the side of the instrument by which the message was forwarded which caused the arrest of Tawell, the Quaker, representing the lines 50 and 100 miles long of those days was placed a modern ink-writing Morse apparatus connected up in one unbroken circuit working direct, *viâ* Teheran, from the Albert Hall itself with Kurrachee, upwards of 5,000 miles. A descriptive lecture was at the same time given by Mr. W. H. Preece, of the Postal Telegraph Department, who lucidly explained the action of the electric current in producing the simple elementary signals. These were made by a needle being attracted to the right

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or left; by forcing a lever for a long or short duration of time against an ink roller, the paper being drawn along the while at a regular speed and thus producing a short or long ink mark; and by actual printing the message in bold Roman type as is done by that marvellous electrical and mechanical apparatus the Hughes' type printer. The most interesting feature of the entertainment was the direct and instantaneous working with India. Kurrachee, the terminus of the Indo-European line in India, was the town selected, and when, in reply to a message of inquiry, that station said, "Here, Kurrachee," and followed it up with the announcement that "locusts are swarming in Scinde," the extraordinary contrast between the announcement and the magnificent Albert Hall and its gaily-dressed occupants was striking in the extreme. After the conversations held with India from the Albert Hall were concluded, the Grand Vizier of Persia, who was at Teheran, sent from Teheran to the Albert Hall a warm message of congratulations to the Prince of Wales, a part of which was as follows:—"Je suis heureux que les rélations entre l'Angleterre et la Perse se sont rapprochées á tel point que, pour ainsi dire, nous pouvons ici prendre part dans la réunion qui se trouve maintenant á Albert Hall." The rapid development of the telegraph under the Post Office was adverted to, and figures were adduced fully confirming the facts; the increase in the number of telegrams sent by the public at the uniform shilling rate, and under the increased facilities afforded, also was instanced as proving that the public quite appreciated the advantages conferred upon them in these respects.—*Times*, June 19th, 1872.

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## TELEGRAPHIC PROGRESS.

A Bill has passed the Parliament of the Dominion of Canada converting the Canadian and European Telegraph Company into the Canadian and Great Northern Telegraph Company. The capital is fixed at 4,000,000 dollars. The length of cable by the route proposed to be opened out by the company would be shorter than existing telegraph cables, and o.. course the cost of construction would be correspondingly less, while on account of its northerly position, the cable would be less liable to accident through the interference of dragging anchors and other causes. The only objection which can be urged against the enterprise is a possibility of interference by the ice; but it is asserted on good authority that there is little or no danger to be apprehended on this account, and the scheme is regarded as easy of construction.

The cable would have to be landed at L'Anse aux Beanes Sebon, on the Canadian frontier, about 655 miles from Greenland and 200 miles from Gaspe Bay. From thence it would be carried to Gaspe, where it would connect with the various telegraph systems of Canada and the United States. The advant-

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ages to Canada of having an independent wire across the ocean in direct communication with Great Britain are obvious.

A submarine cable is to be laid across the Black Sea between Odessa and Constantinople, a distance of about 400 miles. A convention between the Emperor of Russia and the Sultan of Turkey to facilitate the method of telegraphic correspondence was ratified in November, 1871, and has just been published. The contractors to whom authority to lay the cable is granted must complete it within a year.

The Argentine telegraph system now reaches the Andes, Salta, Corrientes, and Misiones. The Transandine line has been opened for service, putting the Argentine Republic in communication with the Pacific.

The Indo-European Telegraph Company have reduced their tariff to India. This company are now speaking daily as far as Bushire, an enormous length of line for direct communication. Excellent signals are frequently exchanged with Bombay, and generally the line appears to be in good order.

The Robert Lowe repairing steamer has returned from an expedition in the Atlantic for executing some repairs to the French Cable. It may be remembered that during the paying out of the cable a slight fault occurred, which could not at the time be localised, and consequently the paying out proceeded the fault being left in the cable. This fault, however, never interfered with the successful working of the cable, but satisfactory tests having been made localising the distance of the fault, an expedition was sent out this summer under the charge of Captain Halpin and Mr. J. C. Laws, the latter as electrician. They succeeded in cutting out the fault at a distance of about 300 miles from Brest, and also a smaller one somewhat nearer the shore. Both faults are believed to be due to causes similar to those detected and cut out whilst paying out. The cable is now in excellent electrical condition.

Captain Halpin has since payed out in the Vanissa a cable of about 330 miles in length, as a "duplicate" between Sydney and Placentia on the American coast. This is to act as a duplicate to the existing cable, the property of the Anglo-American Telegraph Company.

The Robert Lowe has been on the American coast, engaged in the repairs of the French Atlantic, St. Pierre and Duxbury, which has broken for the third time. As the fault was in shallow water, the repairs were executed in a very short time. As this section has been repeatedly broken, steps ought to be taken to remove the cable from the causes which bring about these interruptions.

The Western Union Telegraph Company of America have lately been before the British public in order to raise some money for carrying on some special works for increasing their New York Office accommodation. It is without exception the largest undertaking in the world in a telegraphic sense, and possesses almost exclusively the whole telegraphic business of the United States, their mileage of wire is actually in excess of our Post Office mileage. They possess 60,502 miles of line, and 183,890 miles of wire. Their favourite

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telegraph instrument is the Morse sounder, which embraces about three-fourths of the total number of Instruments. It is a most successful undertaking, but telegraphically considered, they are not so far advanced as the British system. They have, however, recently introduced a new instrument, which is well spoken of, for speaking in opposite directions at the same time on the same wire.

The new General Post Office is approaching completion, and steps are being energetically carried out for the transfer of the head telegraph station there, wires are being laid in every direction, and a large system of pneumatic pipes laid down.

An official report, which has appeared in illustration of the Victorian Telegraph department for 1871, presents several features of interest. The revenue increased in 1871 to the extent of £4,000, as compared with 1870, and since a uniform shilling rate came into operation the business has been doubled.

The extension of the telegraph from Grahamstown to Coromandel in New Zealand is nearly completed.

A company has been formed for the construction of a telegraphic cable from Rio de Janiero to the River Plate. A recent report presented by the directors stated that the sea distance from Rio de Janeiro to Lobos Island, off Molutonado, at the mouth of the River Plate is 1,260 miles, and a few more miles of cable will be required from the island to the main land. The shore once reached, a land line of 90 miles, will establish communications with Monte Video. Monte Video is connected with Buenos Ayres by a cable, and from the Argentine capital a message can be sent quite across South America, the Andes included, to Valparaiso, on the shores of the Pacific. The capital of the Rio Janiero and River Plate Telegraph Company has been fixed at £600,000, and the work is to be pressed forward with vigour.

The director of the International Telegraph Office at Berlin has been instructed by the Italian minister to communicate to all the governments and companies represented at the Telegraph Congress held last winter at Rome that with the exception of Persia and Denmark, all the parties interested have ratified the convention.

Some statistics of telegraphic administration in France, recently collected and made known by M. Blavier, afford information of interest. The service is carried on by three distinct classes of employés, the general staff, the staff for maintenance and repairs, and the telegraph clerks. The *etat-major* is composed of a Director, three Inspectors-General, ten Divisional, and sixty-nine Inspectors.

In 1871 there were 41,248 kilometres of aerial lines, with about 119,405 kilometres of wire, also 571 kilometres of submarine cables, and 18½ kilometres of pneumatic tubes, making a total length of 41,837½ kilometres (26,000 miles) constructed at a total cost of £1,468,000, inclusive of the Algerian cable.

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There were 3,253 offices open, inclusive of 1,228 at railway stations, divided in three categories, viz:

1. Principal bureaux, about 200 in number, despatching not less than 140 to 150 messages daily, and employing from 4 or 5 to 25 or 30 clerks.

2. Secondary bureaux, about 350 in number, most situated at the chief town of the arrondissement, and concentrating the service of the next class.

3. The cantonal, municipal, and semaphoric bureaux, etc.

In 1879 the total number of messages forwarded amounted to 5,663,852, of which only 5 per cent. exceeded 20 words in length.

The annual cost of a kilometre of aerial line, comprising interest and maintenance was about 18s. per mile, and the expense of a single despatch was about the 800th part of a franc, equivalent to the rate of 133½ miles for a farthing.

We learn from America that a short time since the operators in one of the Western Union Company's New York offices were somewhat astonished by the breaking out of a small conflagration underneath the floor in one corner of the office. Water was immediately brought and poured on it, without any apparent effect, and it finally became necessary to cut away the surrounding woodwork, which disclosed the fact that the fire was in a cable of cotton-covered wire saturated with paraffin, through which the lines entered the office beneath the floor. From some cause—probably lightning—a connection had been formed between two through lines attached to large main batteries at the general office, which were connected with opposite poles to the ground. Two large batteries were then connected and thrown in short circuit, developing an intense heat, and setting fire to the inflammable paraffin covering of the wire. If this singular occurrence had happened after the closing of the office at night, it might have resulted in the destruction of the building, and the cause of fire would have remained a mystery. Of course an accident of this kind could hardly have been foreseen, but it serves to point out the necessity of caution in running wires under the peculiar conditions described.

On 3rd inst., a telegram, dated Melbourne, Sept. 12, announced, "The Overland Telegraph to Port Darwin is now completed, and is working splendidly."

The following account is extracted from the columns of the *Times*:—

"A Telegram has been received announcing the recovery and completion by Sir Charles Bright of the Colon and Jamaica cable, the westernmost and last section of the chain of submarine telegraph connecting the United States with the West India Islands, Central and South America, which was commenced by Sir Charles Bright in 1870.

"The cable sent out for this arduous undertaking was 3,600 miles in length, weighing upwards of 8,500 tons, and was divided between seven large vessels,

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and the magnitude of the enterprise, which included the laying of 16 separate cables under greatly varying depths and conditions, and in several cases during rough weather, is unequalled in the annals of telegraphy.

"Many difficulties have to be overcome, especially in laying the shore ends, and providing land lines through dense forests, &c., while the deleterious nature of the climate led to the loss of a number of the staff.

"Owing to the irregular character of the bottom, varying from two to upwards of 2,000 fathoms, four types of cable had to be employed, the first, or shore end, weighing 16 tons to the mile, and the other respectively 5 tons, 2½, and 1¾, the last being covered with galvanized homogeneous iron wire akin to steel. The shore end cable has two massive coverings of galvanized iron wire laid spirally in opposite directions, and all the kinds of cable are further covered with two servings of yarn and Bright and Clark's compound as a protection against the teredo navalis and other marine insects.

"The cables unite Havannah at one end of Cuba with Santiago, and Santiago with Jamaica, whence they extend on the one hand to Colon, and on the other to Demerara, linking up Porto Rico, St Thomas, St. Kitts. Antigua, Guadeloupe, Dominica, Martinique, St. Lucia, St. Vincent, Barbadoes, Grenada, and Trinidad.

"Starting from Havannah, which was previously in connexion with Florida, the line passes across the Island of Cuba to Batabano, where the submarine system commences. From this point, for about 100 miles, the cable is laid along a tortuous course in very shallow water, passing between rocky islets and coral reefs, and the coast being imperfectly surveyed previously, it was necessary to make a most careful study of the bottom, and to sound over the whole of the route to find a soft and safe bed for the cable. The type of cable used on this section being of the heavy class a great deal of manual labour was needed, and it was also requisite to employ a number of small vessels of light draught.

"After passing Cienfuegos the line was laid in deep water along the Cuban coast to Santiago, and the cable was landed amid much rejoicing. The next section laid was to Jamaica, landing it at Plantation Garden River, a work of great difficulty. The next length commenced was that between Jamaica and Colon, where there is a land telegraph across the Isthmus to Panama. The line is one of great importance, and as the traffic and mails from the whole of the western coasts and South America and the central States, comprising Peru, Chili, Columbia, Venezuela, Costa Rica, &c., concentrates at Panama. Shortly after the expedition started from Colon northward, accompanied by Her Majesty's ship Vestal, Commander Hunter, R.N., yellow fever broke out on board the Dacia; three of the cable men were buried at sea, and many others were on the sick list. The weather became bad, preventing observations, when about 300 miles from Colon a fault was discovered a short distance from the ship, and in endeavouring to pick it up an accident happened, and the end

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of the cable was lost. Rough weather followed, and interfered with grappling observations. Upon the return of the Dacia to Kingston a number of the cable staff died from yellow fever, and many others had to be invalided home; and as it was in a bad season of the year for grappling work, it was decided to go on with the eastern sections, and then return to the Colon line.

"The next length completed was between the islands of St. Thomas and Porto Rico, and in succession the rest of the lengths were laid down to Demerara, where, owing to the shallowness of the approach and the liability of ships anchoring over the route, the unusual length of 35 miles of the heavy shore-end cable was submerged, partly from schooners, as the draught of the steamer was too great to allow her to approach within ten miles of the landing place.

"The cable which had been lost between Colon and Jamaica was picked up by Sir Charles Bright on the 11th inst., from a depth of 1,400 fathoms, in latitude 13.58, longtitude 7.82. It was then joined up to Jamaica, and the whole of the lines are now in working order."

There is unfortunately a delay in all West India telegrams, in consequence of the interruption of communication between Havana and Key West. An expedition under General Smith, as previously announced, was engaged in recovering the old cable with the intention of relaying it. Very little news has been received of the operation, and all that is known is that the good cable has been interrupted, and that English assistance has been applied for, in order to restore the communication.

The following telegrams give the latest details of the Australian Cable and overland lines:—

A telegram from the ship Investigator, engaged in repairing the Australian cable, announces that the final splice is made, and that the vessel, having now accomplished its task, will return at once to Java. The fault in the cable occurred at a depth of about 1,800 fathoms. It was immediately localised, and within a few days of the arrival of the repairing vessel at the spot indicated the fault has been successfully removed. As the Australian land lines have been for the last few weeks in working order, telegraphic communications with Australia is now finally established.

"Adelaide, October 21st, 1.7 p.m.—At 12.30 this morning cable communication was restored, and we are now in eager expectation of a message from London. Todd expected in Adelaide in a few days. Land line works admirably. Furnish intelligence to the British press of the completion of this great work. Signed John H. Barrow, Treasurer."

The second telegram was supplemented by a "news" telegram from Melbourne, of October 21st, which appeared in the morning papers of the 22nd.

From Japan we learn that the Mikado visited the telegraph office at Nagasaki, and proposed to exchange messages with the crowned heads of Europe. It was, however, found that the time occupied in transmission would be too long for him to wait, so none were sent.

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The Russian telegraph land lines, connecting with the Nagasaki cable, are out of order through the overflowing of the Amoor river. At last advices the gap was seven hundred miles.

The manufacture of the duplicate French Atlantic cable is steadily progressing at the Telegraph Construction and Maintenance Company's works at Greenwich, about 2,000 miles having been manufactured, of which 1,100 miles have been shipped.

The progress of the Great Western cable at Hooper's Telegraph Works at Millwall is satisfactory, as much as 1,000 miles having been completed. At present none of the cable has been shipped.

The Eastern Submarine Telegraph Company announce that they are about to duplicate their Falmouth and Lisbon cable, calling in at some port in Gallicia, either Corunna or Vigo, in consequence of the increase in the local traffic. An announcement has also been made that a cable is to be laid independently of this Company between the west of England and the northern part of Spain. The intended cable is now being shipped.

*October 27th.* G. E. Preece.

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## PUBLISHING FUND FOR PRINTING THE TRANSACTIONS OF THE SOCIETY.

*The following Circular has been addressed to Members generally:—*

Sir,—Numerous inquiries having been addressed to me, relative to the cost of the first number of our Journal, I am desired to inform you that the Journal has been, and will also in future be, supplied to you free of all cost. The charge of 5s. per number is for non-Members, and those of the outside public who might wish to obtain a copy.

I take this opportunity of calling your attention to the following paragraph in the President's inaugural address:—

"The expense of publishing a complete record of Telegraphic progress will certainly exceed the limits of our subscriptions, and it is proposed to establish a publishing fund, by voluntary donations and subscriptions, which it is hoped will be favorably received. We shall, in this respect, only follow the example set us by the Chemical Society, who have thus succeeded in producing the most valuable record of Chemical progress."

Such a subscription list has been started, and I enclose for your information a statement shewing the amounts already subscribed: and I am now requested to ask for any donation or subscription you may be pleased to offer in aid of the fund for publishing authentic records of the proceedings of the Society, thus

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enabling yourself and other members to obtain possession of what will prove to be a most valuable historical record of the progress of Electrical and Telegraphic Science.

I am further desired to acquaint you that the Journal of the Society will be published as often as "matter" will permit; it is hoped that for the present the publication will be as nearly quarterly as can be made convenient.

As a result of the starting of the fund, the following list of Donations and Subscriptions is given.

I am, yours truly,

G. E. PREECE, SECRETARY.

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THE

# SOCIETY OF TELEGRAPH ENGINEERS,

WILL MEET,

BY THE KIND PERMISSION OF THE PRESIDENT AND COUNCIL OF

The Institution of Civil Engineers,

AT THE INSTITUTE,

25, GREAT GEORGE STREET, WESTMINSTER.

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The Chair will be taken at 7.30 o'Clock on the following WEDNESDAY EVENINGS:—

## SESSION 1872.

| | | |
|---|---|---|
| NOVEMBER ... ... | 13 | 27 |
| DECEMBER ... ... | 11 | Annual General Meeting. |

## SESSION 1873.

| | | |
|---|---|---|
| JANUARY ... ... | 8 | 22 |
| FEBRUARY ... ... | 12 | 26 |
| MARCH ... ... | 12 | 26 |
| APRIL ... ... | 9 | 23 |
| MAY ... ... | 14 | — |

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# JOURNAL

OF THE

# SOCIETY OF TELEGRAPH ENGINEERS.

VOL. I. 1873. No. 3.


The Seventh Ordinary General Meeting was held on Wednesday, November 13th, 1872, Mr. F. I. SCUDAMORE, C.B., Vice-President, in the Chair.

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The Paper read was "ON MILITARY TELEGRAPHS IN CONNECTION WITH THE AUTUMN MANŒUVRES," by Major Webber, R.E.

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Military Telegraphy is not exactly a misnomer; it has one characteristic which makes a difference between it and other branches of telegraphy, and that is, that, from its being only employed actively at times, that is, during war, it becomes the victim and sport of inventors who bring out or attempt to apply to it, all sorts of appliances and inventions. If the suggestions which are made in connection with Military Telegraphy were attempted to be applied to what is called Commercial Telegraphy, I am afraid the latter would not get on at all.

There is at least one thing in connection with the Autumn Manœuvres which is very gratifying—that is, the great interest taken in them, not only by the military public, but by all branches of society; and the large attendance at this meeting to-night is sufficient evidence of the interest which this Society takes in it, otherwise there is no reason for bringing so many telegraphists together to be told how a few miles of telegraph line were erected.

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For the information of those who had not heard it, he might state how it came to be in the power of the War Office to construct that small telegraph system which is shown on the diagram.

At the time when the State took over the property of the various Telegraph Companies, the present Secretary of State for War encouraged a movement by which a military force was attached to the Post Office, to be trained in telegraphy, so that they might in time of war be available for military purposes. Assisted by the officers of the Postal Telegraph Service, this scheme could not but succeed. This force having learnt in such a good school, at a time when the telegraph was being extended all over the country, we hope that what has been done at the Autumn Manœuvres will shew that that assistance has not been in vain, and that those engaged, both officers and rank and file, have profited by that experience.

The arrangement entered into between the Post Office and the War Office was, that the former should lend a certain portion of the Force alluded to, viz., 3 officers and 70 non-commissioned officers and soldiers, together with an equipment in material for building (what may be called) semi-permanent and permanent lines. No such equipment had been hitherto tried in this country, and it was necessary to gain some experience before the best material for the purpose could be decided on; so the Post Office lent to the War Office sufficient material to construct more than 80 miles of telegraph line: with instruments, tools, and appliances; poles excepted. The Post Office also arranged that on the one side the telegraph offices which were in the field of the manœuvres, should be worked by clerks from the Civil branch, and on the other, by a few soldier clerks who were, and are still, employed in Postal Telegraph offices.

I am obliged to confine myself more in my description to-night to the operations which were connected with the Southern Army which were very similar to those of the Northern.

The *personnel* of the telegraph department was a Director, an Assistant Director, one Lieutenant and 35 non-commissioned officers and men (of Engineers), with ½ C. Troops Royal Engineers, composed of 2 officers, 120 non-commissioned officers and men. The visual signalling, which was part of the same department, consisted of 15 officers, and 60 non-commissioned officers and men from the corps in the southern army, forming a total of 22 officers, and 215 non-commissioned officers and men.

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The *materiel* at our disposal was 18 miles of cable, which belonged to the Field Telegraph equipment, and the 42 miles of semi-permanent line.

Before starting on such an enterprise, it is usual to lay down some general idea of what was to be done. It was suggested—

1.—That the Head Quarters of each Army should be always in Telegraphic communication with the base, both when halted, and within a given distance when on the move.

2.—That the Head Quarters should be always in Telegraphic communication with the Head Quarters of any Detachment of the Army which is beyond signalling distance, and nightly with either flank.

3.—That the Head Quarters of each Division should be in communication by Signalling or Telegraph (according to circumstances), with the Head Quarters of each Brigade.

4.—That the Head Quarters of each Brigade furnishing the Outposts should be in signal communication with its Outposts.

5.—It was proposed generally to communicate between Army Head Quarters and the base by a duplicate semi-permanent line between the Army Head Quarters and the Divisional and Brigade Head Quarters by means of the Field Telegraph—and beyond that by visual signalling—both during the day and the night.

The visual signalling was the result of the system which has been growing up in the Army for communicating intelligence. Its advantages have been described in the following way, viz., "its extreme mobility and freedom from hostile attack, while, on the other hand it is peculiarly liable to adverse influences of weather and other coincidences." It was laid down as a general rule that messages should not be sent in the field by telegraph or signalling, where time was not an object, the distance under two miles, and the weather favourable

I will now draw your attention to the diagram, and ask you to observe that the lines —+—+— embrace the general area of the operations of the manœuvres, the black lines being the lines of railway. The sinuous lines representing the streams, are put in to assist the idea of the general form of the ground. The principal towns are inserted, but the diagram is more particularly drawn to show the lines of telegraph and the position of the signalling stations. The semi-permanent lines of telegraph are represented by thick dotted lines, the lines of field telegraph by thin dotted lines, and the signalling stations by flags.

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I am sorry to say I have not complete information as to the position of the signalling stations in connection with the Northern Army, and, therefore, I am obliged to omit the flags on that side altogether.

It having been ascertained in what part of the country the operations of the Southern Army would be likely to take place, two lines of telegraph were projected from Blandford, converging on Tisbury:—

That on the west was carried on existing poles on road and rail, except for a distance of 6¾ miles between Ewerne and Shaftesbury, where new poles were erected. That on the east for 1½ miles on existing poles on the railway, and thence by the direct road on new poles to Tisbury.

The total length of the western line was 19¾ miles, and of the eastern 17½. Of these lines the western one was completed in advance of the movements of the army so far as Shaftesbury, an operation which was necessary, because we had had little or no experience in the use of the materials, sufficient cartage was not procurable, and it was desirable to know at what rate such a line could be erected.

During the stay of the Southern Army at Blandford, one over-head wire was erected on the railway as far as France Farm, and the other to a point intermediate (these distances being included in the numbers given above), to maintain the communication between the camps and the Post Office. The Cavalry Camp was connected with Head Quarters by a short local circuit.

About a fortnight after the army had been collected at Blandford the Head-quarters were removed to the race-course, and a local circuit was made between the Head-quarters camp and the Divisional camp. When one division of the army marched to Bottle Bush, six miles from the race-course, the field telegraph was laid down to a length of 9¾ miles, and remained so for four days.

On the 4th September, which was the day the manœuvres commenced, when the head-quarters of the army moved to Fontmell Magna, the western line was carried into camp by cable, and the office was open early in the day. The overhead line was 8 miles, and the cable ¾: total, 8¾ miles.

On 5th September, when the army moved to Fonthill, the total length of line from Blandford was 19¾ miles, of which 7½ was cable.

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The eastern line was completed on 6th September, when Tisbury, not far from the head-quarters of the army, was in communication by two lines with the base, and on the 7th the line was open for working. The total of overhead line then was 36¾ miles, which, with the cable, made a total of 48½ miles in use.

On 9th September a cable was laid from Wylie to Winterbourne Stoke, 5¾ miles, making a total of 53¼ miles.

On the 10th, the cable from Fonthill to Winterbourne was taken up and a fresh cable was laid from Dinton Beeches to Amesbury, and ultimately carried into the Post office. On that day the total of lines was 41¼ of overhead wire, and 13 of cable=54¼ miles.

The material which was used must also be mentioned, though I must apologize for troubling you with so many figures.

The poles were larch, of about 20 years' growth. To these were attached galvanised pole brackets with ebonite insulators. Where the wire was attached to walls, single wall-brackets were used, and where shackles were used, they were those seen on various lines of railway, called "egg-shaped." The wire was 3-18 strand wire, and the leads No. 7 G.P. prepared wire. The weight of the line allowing about 17 poles per mile, was 18¾ cwt. A certain proportion of tools were in use by the party. The instruments used were the ordinary direct writers, used on the Post Office Telegraphs, and the whole of the material was furnished from Post Office Telegraph depôts, poles excepted.

With the Southern Army, the telegraph was in use 28 days or 370 hours, during which time the communication was interrupted for 106⅔ hours: of this, 8 hours were due to faults in the overhead wires, and 98⅔ to faults in the cable. These faults do not include interruptions on the minor lines, such as that between Bottle Bush and the Race Course. Out of the 28 days there were 21 on which faults occurred, sometimes three or four on the same day. In most cases the fault consisted in the cable being cut by means unknown, sometimes apparently by horses' feet, and others maliciously. On one occasion the cable was cut three times in the same field. The result of all this was that the Army Telegraph could not be depended upon, and there was in consequence a loss to the service, and no doubt a large falling off in the Post Office receipts. Frequently when most wanted, the telegraph was most interrupted. The constant inquiry was—"Can you send a message?" Imagine what our feelings

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would be if the public had to go to one of our large telegraph offices, and make the inquiry—"Can you send a message now?"

The total length of all the Field Telegraph Cable used was 42¼ miles, but that represents not less than 50 miles of cable paid out, because it is necessary to lay down a large quantity of slack, and more cable than is required at times, to avoid cutting the half-mile sections of wire.

The Military Telegraphs were opened for ordinary postal messages, but they carried no press work, which was excessively fortunate. By special arrangement the Post Office decided that military service messages should not be paid for at the time, and thus much time and trouble was saved to the officers, who had not always a shilling stamp, and when there was not a large supply of them. The Post Office made exceptional arrangements in connection with the telegraphs. Those in the charge of Mr. Preece I shall not attempt to describe. I would only mention that the assistance thus given was part of the arrangements that I spoke of. The total number of messages on military service was 487.

THE CHAIRMAN: That is on the military wires only.

Major WEBBER: No, on both military and postal wires, of which those not chargeable were 240, these having been sent on military wires only. The 247 others, were sent on wires partly military and partly postal, and are chargeable. In speaking of the military wires, I speak of all those shown on the diagram. The private messages were 445. The Postal receipts were £41 5s. 3d. The Postal expenses of the telegraph of the Southern Army were £75 11s. 2d. The expenses of the War Office, exclusive of the regimental pay of the soldiers and the outlay in bringing the telegraph train equipment to the point, was £235 4s. 4d.

It will be inferred from these figures that I am not very favourable to the use of a covered conductor lying on the ground as a means of communication. I may enumerate a few of the principal objections to it—namely; the liability to, if not certainty of, faults; secondly, difficulty of localisation; thirdly, rapid deterioration, even with little use; fourthly, a large force of men, waggons, and horses is required in laying and maintaining it; fifthly, the necessity for the use of a closed circuit, which does not allow of its being amalgamated easily with any other telegraph system, and which cannot be carried on in

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its integrity; and finally, even with one man guarding it at every 100 yards day and night, it was not free from injury.

There has been a very great amount of pains taken in organising the Field Telegraphs, and too much cannot be said in praise of those who were engaged in doing it. I will read a short description of it for the benefit of those who may not have an idea how it was performed.

Lieut.-Colonel Stotherd, R.E., writes:—

"Having had the benefit of some experience of the Prussians and Austrians, as well as a very good description of the Italian equipment, the task of organising a Field Electric Telegraph equipment was undertaken at Chatham, and we now possess specimens of carriages and apparatus which seem well adapted for the purposes required to be fulfilled in a light equipment. The instruments employed are Morse recorders and sounders, arranged in a very portable form. The batteries are a modification of Daniell's, and the conductor is Hooper's core. A few light tubular iron telegraph poles are also carried for special purposes. The instruments, batteries, &c., are fitted in travelling offices, which are simply telegraph offices on wheels, and the conducting wire, poles, &c., are carried in waggons adapted for the rapid construction of a line of telegraph. The conducting wire is arranged to be laid on the ground at a minimum rate of two miles per hour; with well-practised men a line has been constructed at a rate of four miles in an hour and a quarter. This insulated cable is not like the Prussian, susceptible of injury by the passage of heavy waggons over it, and it has stood some very severe tests in that and other respects, without injury. The light iron poles are for use at road crossings where continuous heavy traffic would in time produce injury if it were allowed to pass over it. Spikes of a peculiar form are also carried to enable the conducting wire to be suspended to trees or walls in order to meet the contingency of passing through a town or village."

To a certain extent, therefore, the equipment which Lieut.-Colonel Stotherd describes is subordinate, to—that is, it is very much formed, to meet the necessities of, a cable lying on the ground.

There is one difficulty which I mentioned at the opening of my address in connection with military telegraphy—that is, as a rule, it is organised in time of peace. It is necessary to have something to start with, and many things may be introduced in time of peace

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before there is time to use them practically, and which may require slight modifications afterwards. In ordinary civil engineering operations, as we know, it would not be laid down that any appliance is best till it has been thoroughly tried under all circumstances in which it may be used: but in military engineering that cannot always be the case; therefore these military manœuvres have been specially fortunate in enabling us to try this ground cable and come to some conclusion as to whether it is fitted for the work, and whether it should be continued as a means of electrical conduction, or whether some other should be adopted. It is easy to get things quickly when you want them quickly; but then it is too late to try experiments. In time of peace the country will not give the money: and very often a system, such as this use of a cable line on the ground is adopted rather than have no telegraph at all. I think in 1866 it was well known that the Prussians were opposed to the use of the cable line, but there was a mistake in supposing that their objection to the cable arose out of its construction. The cable they used was made by Mr. Siemens, of Berlin—an ordinary core, covered with brass tape. Many thought the objection was in the nature of the cable, but from what I saw myself I believe the objections made to it then are those which I have enumerated this evening. For myself, (I may be much prejudiced, or I may not have tried it sufficiently) I can only say that in similar positions to that I occupied to the Southern Army Corps, I would rather not try it again. I have no hesitation in stating that while the equipment of the Field Telegraph was most perfect, and the energy of all connected with it was very great; I do think the ground cable is a most unfortunate adoption.

I shall be asked what I would substitute for the cable. There is no time this evening to go into particulars or describe in detail what has been suggested by people who have given a good deal of thought to the matter; but in few words I would say if I had again to use a field line, to be put up quickly—almost as fast as the troops march—I would prefer to "hark back" and use what was employed in 1866, viz., a light pole line carrying a thin copper wire. I have heard other suggestions. I think they are fairly practicable, but I have seen nothing to answer the purpose so well or which is so trustworthy a conductor as that. It is not liable to the number of faults to which a cable on the ground is: any person touching it can be more readily seen than in the case of the cable. The localisation of a fault is

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a matter of sight and not of research, and merely requires a man on horseback moving as fast as he can along the line: again, the amount of line from point to point is less than with the cable, no slack being required. With the semi-permanent line of the weight of 17 cwt. per mile we found no difficulty in constructing at the rate of 10 miles per day straight across country. If we were to substitute pole and copper line wire for the cable, specially made, and as light as circumstances will allow, I have no hesitation in saying it could be built as quickly between point and point as the cable is now laid, and the same horse-power which we now have for drawing the cable and its equipment, would carry the same length of line in poles and wire.

I now turn to that part of the Telegraph organization of the Southern Army which includes visual signalling. In the regiments which formed the Southern Army Corps, there had been instructed and qualified at the School of Military Engineering 17 officers and 34 non-commissioned officers; of these 10 and 28 were available, to which were added 10 soldiers instructed in their regiments—giving a total of 10 officers and 38 non-commissioned officers and privates.

On the 19th of August, these available officers and men were placed at the disposal of the Director of Telegraphs, and it was found necessary to add to them 5 officers and 22 men, so that the force might come up to the strength which I named before. The signalmen drew one day's rations in advance, in order to facilitate their mobility. General officers were to give their assistance to the signalling corps, and were requested to have mounted orderlies to carry messages about. During the movements of a brigade, a party of signallers accompanied the column with white flags, so as to be distinguished; but it is doubtful whether in time of war carrying a sign of truce would be a good thing. Those who are acquainted with the code book for naval and military signalling, written by Capt. Colomb and Major Bolton, know that it is necessary to make arrangements in a country occupied by signallers—that is, to give symbols or numbers to points and places in the country, and to the principal towns, &c., so that in describing these, a code number may be used instead of spelling out the long names. This plan was adopted in the country occupied by the Southern Army. Each signalling station had its own number, the total number of signalling stations was 28, the last four being from the telegraph troop. When any station

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called up another, it gave its own number, or in calling gave the number of the station it was calling, and as each station belonged to a brigade it was known what brigade was occupying that ground. Of course, it was necessary with an organization that had never practiced together before, to have preliminary drill. I have said that a certain number of signallers had been qualified, and a certain number had to be taught at Blandford, but it must be remembered that the manipulation of flags is merely the drill of signalling. As soon as a man has acquired the knowledge of sending signals, he ought to go into the field and practice himself in all the circumstances under which he may be called to act; and, it is not till he has had considerable practice in this that a man can be relied upon as a signaller, or to take charge of a signalling station.

Before the Southern Army advanced from Blandford on the 4th September, a certain amount of practice was had, but not so much as was desirable.

I will mention what was done on each day during the actual manœuvres:—

"4th September.—The headquarters moved from Blandford to Melbury, and the advanced guard reached the great ridge. Signal stations were established early in the day on five commanding points between these places, which were in communication with one another by noon. At night, three of these stations communicated by lime light between the same."

"5th September.—Stations were established along the great ridge wood, in communication with others at Fonthill and Ladydown. That night, stations were pushed on to the east end of Grovely Wood, opposite Wishford."

"6th September.—During the attack by the Southern Army on Codford, the extreme right above Wishford was kept in communication with Fonthill, and during the attack of the First Division, its signallers communicated with the rear."

"7th September.—A chain of stations was established from Dinton Beeches along the edge of Grovely Wood to the extreme right above Newton, and a signa party sent in intelligence of the enemy's movements above Wishford, before 9 a.m. to Grovely Lodge to meet the Second Division advancing."

"9th September.—Signal stations were established at dawn above Stapleford and Yarnbury in communication with Headquarters.

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During the action, a signal station was placed across the valley near Dinton Beeches, which observed the enemy's left and advised the First Division of its movements."

"10th September.—Stations were established at dawn, north of Amesbury, near Stonehenge, and at Rox Hill, in communication with headquarters, but were early driven in by the enemy's cavalry."

It was found, that, although, signalling had not come up to what had been claimed for it, either by inventors or those who have encouraged it, there was a considerable field of usefulness: but it was ascertained that this depends upon a minute acquaintance with all possible contingencies, so, that the possibility of failure may be reduced, and that the officer in charge may be able to appreciate the necessity of *supplementing* and *combining* whatever means may be at his disposal. The officer in charge of this little army within an army, must have the confidence of those over him, and a full knowledge of the mind of those who plan and direct operations. He cannot be too early enabled to bring all his resources to bear to procure some result, perhaps one upon which the security of the army may depend. If he fails, then he is unfit (as is every man who fails) for his post. If he is without information, he works in the dark, and he cannot do all he might be expected to do, or provide for the ever-varying requirements of a moving army.

I may mention a few cases—I have many here—in which success, or otherwise attended what was attempted. In the case of the signal stations, I have alluded to, as being posted between Fontnell and the front of the army, it is shown how very small accidents may interfere with the best arrangements. The officers in charge of these stations, who received certain instructions to proceed to the points I have named, all arrived at those places with the greatest expedition possible, but one extra station was sent, to be intermediate, at a place which had not been pointed out. The officer in charge of that station was only to have occupied it in the event of two of the first stations not being able to see one another clearly. As it turned out, not only were these latter stations able to see one another, but even further. However, mistaking (unfortunately) his instructions, the officer first alluded to, occupied the intermediate point, and remained there during the day, thus confusing the signals between the stations on each side of him; and the consequence was, though a large number of messages were sent between station and station through the day,

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they were all interrupted at that point, and during the twenty-four hours only three messages arrived from Stockton Wood at Headquarters at Melbury.

One of these messages, which was received by Sir John Mitchell on the morning of the 8th, was worth the time and pains of establishing these day signals, and employing lime light for night signalling. That message gave a full description of the ground occupied by the Northern Army, and also where each portion of their forces had encamped. The officer in charge of the advanced station, (who I am glad to see here) can testify to this fact—but—I hardly like to tell it to telegraphers—the message was started at five o'clock in the evening, and was not received till one o'clock the next morning! but it was a great satisfaction when we heard they had got it. I must remind you we never anticipated complete success with such a large number of stations; and we claim, that as we were getting experience, we should be applauded for the small success we did gain. The application of the lime light we found to be not an easy thing, at points 900 feet above the level of the sea with a gale of wind and rain falling. Great credit was due to those in charge of that operation, for none of the officers had been in charge of lime lights before: and though they did not succeed in keeping them burning for any great length of time, they did succeed in sending a few signals.

There are one or two things of interest in connection with these operations. We sent a very successful message on one occasion, and in a position in which I think signalling is especially useful—that is for defence. The Southern Army while expecting the attack of the Northern Army, was in a position, that, if attacked, it could not see the enemy advancing. A signal station saw the enemy coming between the hills and the river, on the ground which protected them from the view of the defending Southern Army; and in the messages that were sent, stated, not only, that the enemy was advancing, but also, his strength. The Southern Army was attacked on its right and at its centre. The nature of the ground prevented the Southern Army from seeing the strength of the attack. In a personal combat, one always likes to know whether his opponent is right-handed or left-handed. In this case the enemy was attacking with the greater force on his left, and the Southern Army, by means of these messages was enabled to draw off a certain portion of his force from the extreme left to the extreme right, which was completed when the attack

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arrived, and this gave a preponderance to the forces of the Southern Army over the Northern, at the point required. So that in describing the failures, I think it is due to the intelligence and exertions of all concerned to show that we had some signal successes.

The question has presented itself elsewhere—ought not the means of collecting intelligence, and the means of signalling it, to form part of the same organisation? That may be so. A good signalling officer or soldier, who is well trained, who has a good eye for ground, and in full practice, has all the physical essentials of a good scout. The subject is too large a one to enter on this evening.

During the autumn manœuvres, the army system of signalling was worked in its integrity. There were little deficiencies in the practice of those who had learnt. You have had, in a former paper read here, a description of the waving of flags and lamps for signals, and these are generally considered to be the best practical means; but there is one point which requires modification. I allude to the code system, which, however well it may answer for naval signalling, requires in the case of the army, three persons to do the work of one, and in practice it is found, that in this process, time is lost, which more than counterbalances the more tedious process of spelling out the sentence with the Morse alphabet.

As an example of how little is understood of code signalling, and how disappointing its use may be when applied, I must allude to the result on one occasion, when a General Officer came up to a signalling station which was close to him. Of course he was not acquainted with the details of the means of signalling, or what it could do for him. He inquired if he could speak to a certain detachment of the forces, and was informed that he could. The officer in charge then set about waving his flag to the station, which he ought to have had no difficulty in calling up. The general officer was kept waiting while the flag was waved, no doubt thinking his message was going. At the end of five minutes he inquired whether the message had been sent. "No, sir," replied the signaller who was waiting to see his call answered. Waiting some moments more, the genera becoming impatient, again asked if his message had been delivered? As the officer in charge had only at this moment succeeded in attracting the other station's attention, he received no answer. At length when the message had been sent and the answer was expected, signal was given "repeat No. 11," that number representing a certain group

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of figures which had been sent, but unfortunately No. 11 on one side was No. 12 on the other side; therefore the message had to be repeated, and the officer in despair regretted he had ever attempted to do what he had been asked.

In conclusion I will say I was very glad to see our excellent chairman at the Autumn Manœuvres, and I wish all now present could have been there also, for, I think, not only in telegraphy, but in other things, they might have got a great deal of instruction; and I cannot close my remarks without expressing our acknowledgments to Mr. Scudamore for the resources which he brought into the field, other than telegraph material, which, I assure you, on some occasions were most acceptable.

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## DISCUSSION ON THE PAPER.

The Chairman said in the paper Major Webber had read he had spoken mainly of the telegraph operations of the Southern Army. He (the Chairman) believed they had the pleasure of having amongst them the divisional director of the telegraph of the Northern Army, and he would ask that gentleman whether he could supplement the remarks of Major Webber by his own, with regard to the telegraphic operations of the Northern Army.

Captain Lambert, R.E., said he had had the honour of being Director of Telegraphs of the Northern Army in the recent manœuvres, and he should be sorry that the meeting should separate with the idea that the Field Telegraph failed on both sides. He did not take credit to himself; he supposed it was luck; but the operations of the Northern Army, though considerable, were not so extended as those of the Southern. The Northern Army line was down for 14 days, and during that time he did not think there was any interruption for more than 3 hours. The line was once cut, and several times broken. There was a station every 3 miles along the line: a galvanometer was placed at each station and a continuous current was kept on; the consequence was, whenever a needle dropped it indicated

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a fault, and from constant attention any fault was very quickly repaired. In the case of the Northern Army they were fortunate in passing through a country less thickly inhabited than was the case with the Southern Army, and there were probably fewer tramps and vagrants passing about.

He admitted that the disadvantages of the ground cable line were such as Major Webber had stated; at the same time, there were requirements in campaign service which it would be difficult to carry out with over-head wires. For instance, on one occasion he had to lay about 2½ miles of line in one hour, and to be in readiness to retreat at any moment. He did retreat, and rolled up the 2½ miles of cable in half an hour, and he did not think that could be done with an over-head line. He thought the advantages of Field telegraph lines was that they could be taken anywhere, and be laid for a short time. It was found, from the moisture absorbed from the ground during the night, that the line did not work satisfactorily in the early part of the morning, but it was got into order in about an hour after the sun was up. The operations of the Northern Army were very simple. There was a semi-permanent line from Pewsey, which was the base, as far as Amesbury, entirely constructed by non-commissioned officers and men of the Telegraph Company; and from Amesbury to the scene of operations. The field telegraph was laid first, and was afterwards supplemented by the semi-permanent line. At Winterbourne Stoke, which was the Northern Army head quarters for several days, they had the telegraph and worked it close up to where the forces were actually engaged. They had a front of about 5 miles to cover, and at the moment of attack on the right the General was receiving messages of what was going on on his left, a feat which, up to that time, Commanding Officers thought could hardly be done. The telegraph was also of great service the next day to bring up reserves of Artillery.

With regard to what had been said as to the telegraphs not having paid, if that were the case he thought it was in a great measure due to the want of sufficient publicity of the stations, and it was suggested that in future a flag should be placed on each office to indicate what it was.

Captain Home, R.E., Quarter Master General's Staff, Southern Army, (responding to the Chairman's invitation) said he had not come to speak, but he would state what his experience of telegraphs

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had been. His function was to send messages, and not to make the lines. He thought Major Webber had judged hardly of his own work. He (Capt. Home) sent numerous messages, and Sir J. Mitchell and the whole of the staff found the telegraphs very useful. With reference to the pecuniary results of a line of military telegraph, that was not the way to judge of it. They might just as well come back to the pecuniary value of the army. If they had an army it was quite certain they must have the means of communication, and if they sent only one message it might save an army from destruction. With reference to overhead lines and ground lines, he thought that must be viewed more in a military than a telegraphic point of view. During the manœuvres the Southern Army left no guards on their communications behind. The portion of the army in advance and that in the rear, each required a special telegraph service. The Army being composed of various corps advanced along a considerable front, and, consequently, to carry on the work of the telegraph properly, the wire must be carried along the whole line of operations, and lines also carried right and left. Twelve miles was about an average day's march: they must therefore bring on the lines that distance, and to shift the right and left lines that amount forward every day, he thought this could not be done with the over-head line. The advantages of a ground line were so great as in his opinion to overcome the objections that had been urged against it.

There was another point with regard to these telegraphs. The Prussians in the war of 1866 found it necessary to divide the telegraph operations into two branches; one being the base line, and the other the field line. The former was a line that would be worked by civilians. In Prussia every civilian had been in the army, and when they advanced as they did into France they brought into the service from the great telegraph establishments a number of Engineers and Clerks, who kept up the main portion of the line, while on the right and left of the base line ground lines were employed, worked by soldiers. This was one important point in having a division of the telegraph. In our own country our civilians are not all soldiers, and, if ever we have to take the field, we have a body which could be supplemented by civilians for keeping up the base line of communication. For these reasons it was desirable to have two distinct lines, one military in the front, the other *quasi* civil on the line of communications.

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There was one fault in the overhead line which had not been mentioned. Major Webber had told them the weight of the poles and wire; but he (Capt. Home) had no hesitation in saying the poles were too short, and consequently the weights too light. There were numerous complaints of officers riding, being taken out of their saddles by the wires, and he had practical experience of it himself one dark night. Having short poles and putting them far apart, of course, lightened the weight of the telegraph equipment per mile, but he had no hesitation in saying it was dangerous to reduce the height and to place the poles so far apart as to cause the sagging of the wires to the extent that occurred in the operations described this evening. He repeated that Major Webber judged of his work more hardly than those who saw it were inclined to do.

The Chairman said he had hoped for the presence of Major Baker, who was the Adjutant-General of the Staff of the Southern Army; but there was present Mr. Von Chauvin, who was connected with the Army Telegraphs during the Franco-Prussian war, and he would be glad to hear a few remarks from that gentleman.

Mr. G. von Chauvin said the question raised to-night, viz., that of materials—was one of the utmost importance in military telegraphy. Judging from the experience of the Prussian Army in the war of 1866, and particularly in that of 1870-71, he could say that practicable overhead lines were decidedly preferable to ground lines; but it was impossible to construct the former under all circumstances, as they could not have been maintained everywhere. In cases of villages entirely in the possession of the invading belligerents, although the wires could have been properly watched, the poles would have been knocked down by the passage of war material; and when the army was before Metz and Paris, in the siege of those cities, overhead lines could not be used in situations where they were exposed to the shells of the besieged. In those cases the wires were buried at the back of the trenches, to keep them out of danger.

The Chairman said they had heard remarks from military men connected with the Autumn Manœuvres: they would probably like to hear some from those who had charge of the Post-Office Telegraph arrangements.

Mr. W. H. Preece said that under Mr. Scudamore's able guidance, he had the conduct of the engineering arrangements connected with the

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Post Office Telegraph Department during the Autumn Manœuvres. Those operations, he would remark, took place in a district over which he had control, and probably no part of England could have been selected by the War Department so well fitted to be served with telegraphically as that which was fixed upon. It happened that through the base of the operations of the Northern Army, and through the very centre of the country where the campaign took place, the Postal Telegraph Department had main trunk lines; the result was they were able to meet, in a complete way, the requirements of the public.

He wished, in the first place, to disabuse the minds of those present with regard to the commercial results of the telegraph. He considered them most successful. During the period of the manœuvres, *not* 240 messages passed over the military wires, *but* no fewer than 13,000. The public appeared to thirst for information, and the newspaper press went into the matter with an energy and spirit that was astonishing. *The Scotsman* sent no fewer than four correspondents to the seat of war, and the result was, that no less than half-a-million of words embracing nearly 300 columns of news were sent by means of the Postal Telegraph wires, with the greatest rapidity, precision, and success. He was glad to be able to commence his remarks with a narrative of success, because they had heard from Major Webber a history of failure, but as experience came from failure they might hope in future to reach that state of perfection which all desire to attain. The precise statistics of the manœuvres would be given by Mr. Johnston, who was the chief of the special staff employed on that occasion, and the results they would find were very successful indeed. He might mention that Salisbury was so conveniently placed with regard to wire communication that they were able at the same time to communicate with London, Manchester, Leeds, Edinburgh, Glasgow, Plymouth, Blandford, and Southampton. At one time from Salisbury, they maintained four circuits, working direct to Edinburgh, and they worked with as much rapidity and precision as those to the nearer place—Southampton. The press communications were worked with the greatest speed, as was testified by the fact, that on some occasions the morning newspapers contained six or seven columns of intelligence of the campaign, the whole of which, was transmitted by telegraph.

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With regard to the military telegraph, he thought the observations about the defects of the wires were just. When a similar subject to this was under discussion a little time ago, he took occasion to make a similar remark to what he was now about to do, in which he had been confirmed by the experience of the last year, viz., that he thought the War Department should replace the defective wire they now used with something more substantial, and less liable to damage. He also called attention to the apparatus used by the War Department, and alluded to the advantages which he considered would be gained from the use of sound in the place of recording instruments. He was met in those remarks by a gallant gentleman at the council table: but he was more than ever confirmed in the opinion that to obtain simplicity and accuracy in working it was necessary to introduce into military telegraphy sound rather than signs. It was found by experience that sound was not only more rapid, but more correct, and more suited for military purposes than the cumbrous recorder now in use. With regard to the semi-permanent lines, Major Webber mentioned that the stores were supplied by the Postal Telegraph Department: in fact it was a Postal Telegraph wire. There was one occurrence which struck him, and that was that the line was erected in advance of the army. Of course when an army advanced in an enemy's country the telegraph must succeed the army, it could not precede it. The Northern Army line was worked entirely by Civilians; the Southern, by Sappers and Miners. He did not know how far it was due to the existence of the civilian staff of the northern line that the work was so superior to the other, but it rarely failed, rarely broke down in the communication between head quarters and the base. On the other hand, in the Southern line, there appeared to have been constant interruptions and breaks-down, and the communication could never be depended upon between the base of operations and head quarters. Under the immediate orders of his distinguished chief in the chair, the staff watched with anxious care the fate of the country; they watched from a hill the approach of the enemy; and, on one occasion, he saw a man at the bottom of the hill waving a flag violently—in fact, he seemed to be "calling"—on which he called the attention of the signalling man near him, and asked him whether he understood the signal, to which he replied in the negative; adding, that the man was only a Rifleman. That led him to suppose that there was an absence of


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system in distinguishing, not only one side from another, but different members attached to the same side. They had heard a record of failures to night. He was in hopes to have heard something of the effect of the telegraph on the tactics and strategies of military manœuvres, and that military telegraphy had advanced; but he was sure, if the late campaign in Wiltshire had the effect of pointing out its defects and how they might be remedied, the expenditure would not have been lost, because there could be no doubt in all future movements of armies the telegraph must play a most distinguished and important part.

Mr. Latimer Clark remarked that he was more than ever impressed with the importance of telegraphy as adapted to military purposes. They had heard a list of failures from Major Webber, but he was glad to hear from another gallant officer that Major Webber had greatly underrated his own performances; he was not surprised to hear that wire, laid on the surface of the ground, was a failure; he would rather have been surprised if it had succeeded. He imagined that in actual warfare the ground line, instead of being laid on the surface, would be buried beneath it, and in such positions he had no doubt that wire might be relied on for a considerable time, especially if some better and stronger form of wire were employed. He thought it possible to make use of a suggestion which he threw out the last time this subject was discussed—that was the use of a kind of plough which would rapidly deposit the wire in the earth; by that method he calculated that a wire could be laid along road sides about a foot deep by one horse at the rate of fully four miles an hour.

He had had occasion some years ago to report on this subject at the instance of the late Chairman of the Electric Telegraph Company, Mr. John Lewis Ricardo, and he recommended that for temporary flying lines they should use bamboo poles, with insulators covered with vulcanite; that No. 16 gauge wire should be placed on these, and that the wire should be hoisted on the poles and strained up by twisting the poles round. He should not recommend the use of copper wire for military telegraphs: for those short lengths of line small iron wire would do equally well, and it was of so little value that it might in all cases be thrown away. Major Webber had spoken of his many disappointments and failures, but had scarcely alluded to his successes. He could not help feeling that practice would bring perfection, and though his gallant friend succeeded but

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partially on the last occasion, he felt that the services he had rendered to the army were very great, and quite sufficient to justify him in expecting great future success.

Captain Le Mesurier, R.E., said the military telegraph had been dragged out of the mire in which it was placed. He would say a word about visual signalling with a view to relieve it from some of the disparaging remarks that had been applied to it. He had not had the wide experience of some present, and relatively to Major Webber he was as the school teacher to the professor. He had been occupied only in teaching the A B C of the system and the reading of the visual signals, but his knowledge of the details led him to take exception to some of the statements that had been made, and to endeavour to point out what he considered was the cause of failure. In the first place he thought there were not enough men employed, and that there ought to have been 112 officers and men instead of 75. In the next place he thought the want of sufficient practice of the men occasioned failure. With regard to the lime light mentioned by Major Webber, it was not only an excellent invention, but would stand a high wind; but, like all other lamps, it required fuel to keep it alight, and he understood they ran short of materials for making the necessary gas. There was another point—with regard to the use of the code. He believed the inventors of the code were present. He had used it a great deal, and he would say in the hands of well-trained, intelligent men the code was of the greatest use. He himself would generally use it in preference to the alphabet. In the hands of unpractised men he granted that the code would break down, and so would visual signalling of any kind. It had been said that telegraphy was not appreciated in the army as it should be, because commanding officers did not properly know the use of it: much more was this the case with visual signalling; and this opinion was confirmed by an account of the signalling operations during the recent manœuvres given him by an officer of a distinguished cavalry regiment who took an active part in them, and who declared that, after his party had been mistaken for camp colour men, he did not care to be so employed again.

Mr. R. W. Johnston, who had the pleasure of being associated with Mr. Preece in the control of the staff and working arrangements, while pointing out that Major Webber's statistics as to the number and value of messages referred only to the work passing over the

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military wires, thought that the meeting might be interested to know the total amount of work done by the Post Office in connection with the Autumn Manœuvres, and read the following statement:—

## POST OFFICE TELEGRAPHS.

**Return of Special Work done in connection with the Autumn Manœuvres, 1872.**

| | Ordinary Messages. | | Press Messages. | | | Total Value of Special Work. |
|---|---|---|---|---|---|---|
| | Number Forwarded and Received. | Value. | Number Forwarded. | Number of Words. | Value. | |
| | | £ s. d. | | | £ s. d. | £ s. d. |
| Salisbury District ... | 5,924 | 301 6 8 | 323 | 322,296 | 169 2 6 | 470 9 2 |
| Blandford „ ... | 4,331 | 228 11 4 | 173 | 133,417 | 79 14 4 | 308 5 8 |
| Amesbury „ ... | 2,205 | 123 19 6 | 88 | 23,688 | 13 11 0 | 137 10 6 |
| Pewsey „ ... | 1,162 | 62 8 9 | 75 | 50,624 | 30 1 8 | 92 10 0 |
| Miscellaneous ... ... | 300 | 19 6 5 | ... | ... | ... | 19 6 5 |
| Total ... ... | 13,922 | 735 12 8 | 609 | 530,025 (265 Columns.) | 292 9 1 | 1,028 1 9 |

Mr. Johnston added that between 30 and 40 clerks were specially employed throughout the district embraced by the Manœuvres, and that in many cases the simplest forms of instrument in use by the department were replaced by the most complicated, in order to secure efficiency and speed in transmission. Thus, Pewsey, whence the communication in ordinary times only extends to Marlborough on an "A B C" circuit, was enabled to work through direct to Manchester, Bristol, and London; while Amesbury had its "A B C" instrument replaced by no fewer than three single current printers. At Salisbury and Blandford the increase of facilities was, of course, on even a greater scale; and the former place, whose communication does not usually extend beyond London on the one side and Southampton on the other, was placed *en rapport* with Manchester, Liverpool, Edinburgh, Glasgow, and several other distant towns. In each case offices had to be specially fitted up for the occasion, and were kept open on an average 18 hours a day, as compared with a little over 12 hours in ordinary times. A semi-military station, worked by postal clerks, was also

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established at the little village of Upavon, during the stay of the troops in that district; and a "flying column" of special telegraphists accompanied the army back to Aldershot.

Captain Colomb, R.N., would offer a remark or two with respect to visual signalling. Captain Le Mesuerier had said the inventor of the code used in the Army was present. The real inventor, however, was Sir Home Popham, who died in 1820, that could hardly be the case. The code used in the Army was simply an adaptation of that of Sir Home Popham to the service for which it was intended, and was but a numbered dictionary, the sentences taking the place of words by numbers, so that a number of messages were condensed into a small number of figures. Major Webber made allusion to Major Bolton and himself (Captain Colomb) as in some degree the originators of the Army signals. The true originator was the late Sir John Burgoyne, many years back; in 1857, Sir John Burgoyne sent for him to the War Office, to ask him to see what could be done in the way of establishing army signals, such as were in use in the Navy, and what had been done in the Army since then was a development of Sir John Burgoyne's idea; necessarily a great deal of the visual signalling in the Army had been taken from that of the Navy, because in the latter they had had ample experience in signalling, whereas in the Army they had no experience till then. This was to be said—that those in the Navy must not press their views upon the Army too strongly. It might be that what suited the Navy admirably would not be found in the course of years to suit the Army; at the same time both services were striving for one object—that was, so to arrange and modify the system of visual signalling in the Army and the Navy that, with a system common to each service, the two services might be in perfect communication with each other whenever it was wanted. He agreed with Major Webber that visual signalling for the Army was highly desirable. The matter of merely instructing men in the use of the code was one that could be accomplished in a very short time, but when they went out into actual service there were so many contingencies different to what their experience had been hitherto, that there was great liability to faults and failures. He hoped the failures which had been recorded in the last Autumn Manœuvres would not stop the practice of visual signals, but rather encourage them, and he hoped the officers in charge of the whole system of visual signalling in the Army would, on

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another occasion, have an opportunity of seeing the system in actual use in the field, and bringing it to perfection.

The Chairman said, before he asked the meeting to do what he was sure all would be anxious to do, viz., to pass a vote of thanks to Major Webber for his paper, he would like to make a few remarks upon the discussion. In the first place, he had been amused by the little friendly contest that had taken place on the financial aspect of the question between Major Webber and Mr. Preece and Mr. Johnston. For his own part he could confidently say he never expected to get a shilling out of the military wires, and was surprised that they had got anything at all: for when they lent the plant necessary for the construction of these lines to the War Office, profit was not at all in their minds. What they thought was that it was incumbent on a great national establishment like the Post Office to aid, as far as possible, in a great scheme for the defence of the country: and whether the cost was a few pounds more or less never entered into the mind of the Postmaster-General. So when Major Webber asked for the supply of the plant which they had, they promised it should be forthcoming, and also that any assistance which the department could give would be readily afforded: and they never for a moment imagined it was necessary to look for any pecuniary results from these lines. In fact, he did not know up to that moment that there was any commercial traffic over them, and he should go away with a sense of having gained something more for the Chancellor of the Exchequer than he expected. Major Webber had told them that the Post Office lent the plant for the construction of the lines. Upon that he would add that, for their own purposes, they had always in store a large amount of spare material and instruments, which were kept as a sort of insurance against fire: for they knew that if one of their large offices were destroyed by fire the mere value of the instruments destroyed would be nothing compared with the loss of revenue that would ensue while other instruments were being manufactured to replace those lost. Therefore they kept a considerable stock of spare materials and instruments which would serve the country in the not impossible event of fire: and in the not very probable event of foreign invasion he had no doubt they could supply the country with any amount of materials. Major Webber had given a catalogue of failures. He did not think that was quite his intention. He had depreciated his own efforts very un-

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necessarily, and had not done justice to his own forethought before the manœuvres commenced; and his personal labours whilst they were in operation, when as he was often sixteen or eighteen hours per day in the saddle. It might be thought that the military telegraphy was carried out under favourable circumstances because it was done in a peaceable country. He (the chairman) was inclined to think that the circumstances were unfavourable, and that the ground lines suffered from the fact that the country was at peace, and that it was only mimic warfare. His own observation was that the line was more cut by wheels than by anything else. If the nation had been at war, they could not have had the traffic of endless cabs and waggonettes full of pleasure parties traversing the country embraced in the campaign, and doing damage to the cable at almost every 100 yards. One other remark he would make. A sort of comparison had been drawn between the civilian manipulators and the military manipulators. He did not think that was quite fair. He would not make the comparison as between the civilian and the soldier, but rather between the man in practice and the man out of practice. There was no reason why a soldier should not be as good a manipulator as a civilian, if he had as much practice. They had been told that an enormous amount of work was done to distant towns at a high rate of speed: but Mr. Preece forgot to tell them that the man who did that work was one of the best telegraph clerks in the service, and no military manipulator had had the constant practice which he had had: and if the War Office wanted in time of war efficient manipulators, they must not look for them from amongst men who learnt the work for a time and then left it, but they must look to the young men in the civil service of the crown; and they must offer them some inducement to go out and serve the country in that capacity either at home or abroad, and then they would have the pick of the service—men who knew how to manage the instruments and adjust them. He believed Major Webber had some scheme of that kind in contemplation, and he would probably tell them that was what the War Office intended for the future: that they would not rely entirely upon soldiers who, whatever skill they might acquire in the school, lost it after they left the school, but that they intended to have at hand a staff who, when occasion required, would be ready to cast off the civilian uniform and take that of the army. In conclusion the chairman proposed a vote of thanks to Major Webber for his paper, which was carried by acclamation.

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Major Webber having thanked the meeting for the kind reception accorded to his paper, said—Captain Home and Mr. Preece had described between them, he thought, a good deal of the causes of the failures. He (Major Webber) *would* say he had not anticipated so many failures. He had more particularly alluded to two; one being with the cable, and the other in connection with the system of signalling. One knew, when sending a communication by any means, though everything in the main might be perfect, it might go wrong from a very small defect. He had described two small defects. They occurred in the means of communication and affected the results; but given the results, there were fewer failures than he expected. Capt. Home, in saying military telegraphs should be divided into sections, described the cause of the failures in the Southern Army lines. Capt. Home said it should be divided into field line and semi-permanent line. They were unable to keep up this distinction in the Southern Army line but were obliged to use both together, and when one broke down the whole failed, while in the Northern lines one did not affect the other, because they were not obliged to use them together. If they had a telegraph system at all, they must be able to use one part with the other. They never knew whether they had to carry the telegraph to the rear or to the flank, and never knew when they had to apply one system or the other: therefore he claimed that the systems should be adapted one to the other; but, in the case of the Southern Army, the one system was not as perfect as the other, and they ought not to have been used together. He might have been too critical on what they did, but his telegraphy had been learned in a very perfect school, and he had hoped to make his military lines as perfect as his postal lines. He was not able to do that, and was obliged to do the best he could. As to the comparison in a commercial point of view, perhaps he was wrong to give it; but he did not give it as a means of judging of results, because, as Mr. Scudamore said, it was not contemplated that the thing would pay in a commercial point of view; but he wanted to shew that in the 200 hours during which the lines were at work they did a certain amount of work, but, owing to the repeated interruptions, that amount was considerably curtailed. His only hope was that they would be able to profit by the experience which they had gained.

With reference to the comparison drawn between the civil and military clerks by Mr. Preece, he had only to remark, that, the good

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working of the Northern lines had nothing to do with the clerks, more than the bad working of the Southern lines. If such had been the case, the defect would have been due to the Postal Telegraph Offices in which the military clerks had been trained. But it was not so, as nothing could have exceeded their efficiency and zeal.

The meeting then adjourned to the 27th November.

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The Eighth Ordinary General Meeting was held on November 27th, 1872, C. W. Siemens, Esq., F.R.S., President, in the Chair.

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The Paper read was "On Lightning and Lightning Conductors," by W. H. Preece, Esq., Member Inst. C.E., and S.T.E., &c.

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The number and intensity of the thunder storms which have raged over this country during the past season, as well as the accidents which have accompanied them, have been so far above the average that they have attracted unusual attention to lightning and the means at our disposal to protect ourselves, our buildings, and our apparatus from the destructive effects of electrical discharge. This, therefore, forms a most interesting subject for discussion before this Society. Recently the partial destruction of that magnificent building, the Escurial, one of the chief glories of Spain, and called the eighth wonder of the world, has added considerably to the interest felt in the subject.*

In this country, not only have trees been shattered, cattle destroyed, public buildings struck, and private houses injured; but human beings have been killed in such numbers, that if tabulated, they would probably cast into the shade the massacre committed by even our railway trains. The average number of deaths due to lightning in England, previous to this year, was 18; in France it was 95.

Mr. Symons, the well-known meteorologist, who has for many years devoted much attention to this subject, mentions that in two storms in June last nearly two hundred separate accidents came under his

* The Escurial, since its completion, in 1584, has been on fire no less than seven times, viz., in 1587, 1590, 1671, 1744, 1766, 1826 and 1872. The causes of two of these are unknown; but, at least four of the fires arose from lightning, yet there never has been one lightning rod introduced into the Palace.

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own knowledge, including the death of ten persons and injury to thirty-three others; upwards of sixty houses were struck, ten or fifteen of which were burned down. Twenty-three horses and cattle and ninety-nine sheep were killed. This is the imperfect record of only two storms. What must it be for the whole year?

But it is the damage done to our telegraphic system that more immediately interests this society. I am able to give fairly complete returns of the injury inflicted on the apparatus and plant of the Postal Telegraph Department, and I am in hopes that the discussion which this paper is intended to inaugurate will elicit much important information of the damage done to our extensive Railway Telegraph System. From January 1st to July 31st 1872, of 9475 instruments of different form in use in the department, 897 or 9.46 per cent. were injured.

## I.—Atmospheric Electricity.

I do not propose in this paper to discuss the cause or nature of atmospheric electricity. It is sufficient for our purpose to admit the distribution upon the surface of our earth and in our atmosphere of that great form of energy called *Electricity*. To study the effects of *Heat* it is not necessary to discuss its nature, and the great laws of *Gravity* have been determined without reference to the inscrutable mystery of its causation. I, however, do not hesitate to assert it, not only as an opinion, but as a fact well substantiated by experience and by reasoning, fathered by the greatest lights of our science and taught by our leading philosophers, that electricity is no more matter than is heat, or light, or sound. Modern physicists know no such thing as the so-called electric fluid, *as a fluid;* that is, Electricity does not exist as a mass or substance occupying space, and moving from point to point in such a way as to justify the assertion so often made that "it enters here and makes its exit there." It is one form of energy, and therefore necessarily *force* and not *matter*, displaying its effects in various useful, beautiful, and terrible ways. While the early theorists have imparted into our language terms based upon the hypothesis of a fluid—notably "current"—there is no objection to the continuance of these terms, provided they do not convey to the mind erroneous ideas as to the nature of the force whose effects they symbolize. A current of

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electricity is a clear, well-defined term, raising in the mind at once an idea of its character; but it by no means implies the transference of matter from one point to another.*

Thunder-storms are but gigantic repetitions of simple experiments. They are but elementary electrical phenomena, differing only in degree from those which cause the ordinary snapping spark from the machine, or the loud report from the Leyden jar. Electrical discharge, whether indicated by a *current*, by the *brush*, by a *star* or *glow*, or by a *spark*, depends simply upon the existence of two points at different potentials, separated in the first case by a conductor, in the latter cases by a non-conductor. In the case of the conductor, we have the ordinary electric current, and in the case of the non-conductor when the difference of potential is high enough, we have the disruptive discharge, accompanied with its usual explosive and luminous results. In any case of electrical discharge, either that indicated by a spark from a lump of sugar, by the disruptive discharge of a Leyden jar, or by a flash of lightning, there must be two conducting masses in opposite electrical states, separated by a non-conductor or dielectric.

These masses may be two thunder clouds, or the earth and a thunder cloud, oppositely electrified, separated by the air, forming the simple conditions of an ordinary condenser.

The discharge, whether from a Leyden battery, or from Heaven's Artillery must be instantaneous, and continuous along its whole path. The light we see is the effect of the discharge. It is indeed as its colour and as the spectroscope has shown us, simply incandescent matter. It indicates the path of the discharge and nothing more. When lightning is seen the danger is past. Persons who have been killed by lightning can have seen nothing of it. Their death must have been instantaneous. The placid state of their features is an indication of its painlessness. Persons who have been struck have stated that they have seen nothing and only felt a blow.†

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* I define the technical terms used in this paper as follows:—

1. *Quantity* is the magnitude or amount of Electricity present.
2. *Potential* is that function of Electricity which determines its motion from one point to another,
3. *Dielectric* is the non-conducting medium, through and across which inductive action occurs, which terminates in discharge.
4. Two Conductors, separated by a Dielectric, constitute what is called a *Condenser*.

† Tyndall says:—"The nervous system requires a certain interval of time to become conscious of pain. The time of an electric discharge is but a small fraction of this interval; hence as a sentient apparatus, the nervous system is destroyed before consciousness can set in. If this be true, and there are the strongest grounds for believing it to be true, death from lightning must be painless." (Notes, p. 16.)

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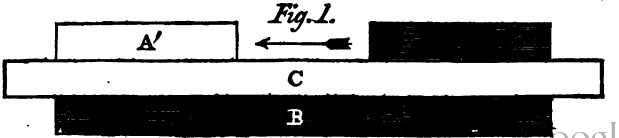
The magnitude of the discharge depends upon the quantity of electricity present, and the distance through which it occurs. The path is prepared beforehand by induction. The particles of air or other matter in its path are raised to such a high state of polarization, that they are in a state of "tottering equilibrium," and the slightest acquisition of potential or diminution of resistance, either by approach of the conductor or increase of quantity destroys this condition, and we have discharge with all the effects of light, heat, and mechanical energy. A ship sailing calmly over the ocean, a moving railway train, a horseman galloping home for shelter from the approaching storm may prove the last straw to break this camel's back.

The air which we breathe is invariably found all over the surface of the earth to be in a state of electrification. It is usually positive in fair weather, except a thin stratum in contact with the earth. Its potential increases as we ascend; but even at the same place, its potential and character vary at times, particularly when thunder is heard in the distance.

It is usually assumed that the great masses of clouds, called thunder clouds, are themselves the generators or sources of those great charges of electricity which result in thunder and lightning. It is, however, very doubtful whether this be so; but it is more probable that the clouds merely act the part of the coatings of a Leyden jar to accumulate and concentrate the charge in points. Clouds have even been known to be absent when a discharge of lightning has been evident; and discharges have frequently been observed to be repeated from the same cloud. Moreover a very simple and well-known experiment shows that the charge of a Leyden jar exists—not in its coating,—but in the dielectric which separates its coatings. In the same way a charge which terminates in a thunder clap exists in the air and not in the cloud.

There is a beautiful experiment of Franklin's, which illustrates the accumulative action of a cloud moving through polarized air.

*Fig. 1.*

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1. Apply a charge to A and draw it gently to $A^1$. The charge will be found distributed.

2. Reverse the motion, the charge will again accumulate on A.

3. Charge the entire surface by a removable coating, then draw A gently to $A^1$—discharge will take place two or three times during its motion.

A represents the cloud, B the earth, and C the air.

Thus a moving cloud may merely act the part of a carrier or accumulator of the charge which exists in the air.

Lightning is usually classified into *sheet*, *forked*, and *ball* lightning. *Sheet* lightning is merely the reflection of forked lightning, or the electric discharge which has occurred somewhere out of the field of view. *Forked*, called also *zig-zag* or *chain* lightning, is the light produced by the disruptive discharge between cloud and cloud, or between cloud and earth. *Ball* lightning is of a very different character. Many of the so called "balls" are undoubtedly optical illusions, and Faraday himself stated that they were incompatible with what we know of electric discharge. "There may be balls of fire," said he, "but they are not electrical." Yet the evidence of balls of blue fire rolling along the surface of the sea, and suddenly terminating in terrible electric discharges over ships; masses of fire rolling along the ground towards buildings, ending in fatal discharge, and many other cases, leave it unquestionable that some such phenomenon as globular or ball lightning exists. Some have explained them to be balls of incandescent gas, rendered so by the discharge; but Mr. Cromwell Varley has recently offered a more acceptable explanation. According to him, ball lightning is a luminous spot on the earth, terminating a current or brush discharge from a negatively charged cloud. This spot moves with the cloud. Illuminated lines of force are projected from some point in the cloud upon the earth. He has been very successful in repeating the effect experimentally, and he suggests this fact as an explanation of the photographic images imprinted on the skin of persons struck by lightning.*

I quote from Faraday: "When after a serene sky thunder clouds form in the distance, the observer sees the clouds and the illumination of the lightning displayed before him as a magnificent picture; and what he often takes to be forked-lightning (*i. e.*, the actual flash, and not

* C. F. Varley, Trans. Royal Society, January, 1871.

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the reflexion of it) appears to run through the clouds in the most beautiful manner." "That which is thought to be the electric discharge is only the illuminated edge of a cloud, beyond and behind which the real discharge occurs. It is in its nature like the bright enlightened edge which a dark well-defined cloud often presents when between the sun and the observer, and even the moon also frequently produces similar appearances. In the case of its production by lightning and distant clouds the line is so bright by comparison with the previous state of the clouds and sky, so sudden and brief in its existence, so perfectly defined, and of such a form as to lead everyone at the first moment to think it is the lightning itself which appears." . . . . Hence many of the errors made as to the character, shape, and condition of the lightning flash.*

The discharge of a Leyden jar, of an induction coil, or that which is succeeded by lightning and thunder invariably occurs along the line of least resistance. It has been found, in every accident which has been investigated, to follow the ordinary laws of the transmission of electricity, laws which are simple and thoroughly well known. This line of least resistance may be made up of metals, of bricks and mortar, of trees, or of animal flesh. Whatever in fact offers the least resistance will be the chosen path. It need not, necessarily, be a single track, for both in experiment with machines and with induction coils, as well as in the observation of the great experiments of nature it is frequently found that the path is bifurcated, and often divided into three or even into four lines. Thus the electric discharge in the air is a simple case of the electric discharge between two electrified conductors which have acquired such a difference of potential as to break through the resistance of the dielectric which separates them, violently displacing its particles, and completely altering its physical features.

There is nothing hidden, mysterious, or unknown in the laws of atmospheric electricity. They are simple cases of the ordinary well-known laws which are as "familiar in our mouths as household words."

## II.—Its Effects.

The effects of atmospheric electricity are, perhaps, better known than those of any other other natural phenomenon. They have been principally studied in their destructive results upon ships, upon

* Faraday, vol. 2, p. 277.

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buildings, upon human beings, and—in our own particular sphere—upon the instruments employed for telegraphic purposes. The case of a ship is very different from that of a building, or an apparatus within a building. A ship is a prominent object—generally a conductor—situated upon a plane—the sea. It thus, if a thunder cloud passes near it, at once reduces the line of resistance between the sea (the inner coating) and the cloud (the exterior coating) of the condenser, determining discharge. Hence it is that, so often it has been observed that a heavy black cloud is approaching the ship; and, without any previous warning whatever, a great flash of lightning or an apparent ball of fire has seemingly descended upon the ship, followed at once by an awful clap of thunder. On the other hand, buildings form but an insignificant feature in the large irregular area exposed to induction from a charged cloud. Trees and buildings take but a portion of the charges which in the case of ships have fallen in their whole intensity upon them. Except in the case of very prominent church spires, columns, &c., it is probable that the effects upon buildings are immeasurably smaller than upon ships. Again, in the case of human beings it is probable that but a small portion of the discharge passes through them; while in the case of telegraphic instruments the quantity of electricity which passes through them is still smaller.

From these causes, the methods that have been adopted for protection based upon the damage inflicted on ships, have probably led to the adoption of unnecessarily costly and superfluous measures to protect buildings and instruments.

We, in this Society, are more interested in the effects of lightning upon instruments, and upon the apparatus constructed for the transmission of telegraphic despatches, though we neither ignore nor neglect its effects in other fields.

The accidents that telegraphs suffer from might be divided into three classes:—

1. Those affecting the wires;
2. Those affecting the poles; and
3. Those affecting the instruments.

Each of these classes may be sub-divided into those which are the result of the *direct discharge*, and those which are the result of *induction*. In the first case the wires, poles, or instruments form a path or circuit for a portion of the discharge itself; in the second

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case they are influenced by currents which are induced by the approach, recession, or sudden neutralization of charged clouds.

1. (*a*) DIRECT DISCHARGE.—The direct effects are not nearly so numerous as the induced. In the case of open wires, the discharge forms but rarely anything more than an instance of the passage of a very powerful and instantaneous current. Cases have occurred, however, where this current was so great as to fuse and destroy the line-wire; but such cases are very few and far between.

During the past season I can find but two cases where our line wires—viz: No. 8 wires—have been absolutely fused.

*(b.)* INDUCTION.—It is evident that the accumulation of a charge upon a cloud converts it into a very powerful inducing body. As the cloud approaches the line it induces in the section of the wire nearest to it an opposite electrical state, and as this change of state is gradual, a current of sensible duration must be observed; but when discharge takes place and the cloud suddenly loses its coercive power, the wire as suddenly recovers its neutral condition, producing a powerful current in the opposite direction. Hence, during a thunder-storm, wires are pervaded by repeated currents which ring bells, demagnetize needles, throw apparatus out of adjustment, shock clerks, and make false signals on railway block instruments. During the construction of the Hoosac tunnel, two premature explosions of blasting charges were caused by these currents, producing serious and fatal results.

Not only the over-ground wires are affected, but those buried two feet deep under-ground. I print as an appendix to this paper a very interesting correspondence which took place in 1854 between Faraday and Messrs. Latimer Clark, and Culley upon the demagnetization of needles upon the long underground circuits between London and Manchester, and very recently (July, 1871) while some joints were being made upon the new under-ground wires between Manchester and Liverpool, the jointer was alarmed by a succession of crackling sparks passing from the wires to his box, which was in contact with the ground.

2. In the cases of poles, it has been found that when the pole has formed a portion of the path of the discharge, it has been, in the case of an unprotected pole, shivered to atoms, and one instance occurred where twenty successive poles were very nearly totally destroyed. Usually, however, a discharge which has taken the wire in its path, divides itself amongst several poles, and cuts out, with the smoothness of a gouge, grooves from the top of the pole to the bottom

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3. In the case of instruments, the effects have been:—

(*a*) From DIRECT DISCHARGE.—Currents of such a strength as to absolutely burst out the cases, burn the woodwork, and fuse the wire of the galvanometers and electro-magnets. An exceptional case of accident has arisen from the wires passing close to gas pipes and the discharge passing across the air fusing the pipe, lighting the gas, and setting the station on fire. Such cases are, however, rare.

(*b*) INDUCTION.—The induced currents being instantaneous and very strong, demagnetize or reverse the polarity of magnetic needles such as those of galvanometers. This was a very prolific source of trouble in former days, but we have recently introduced induced needles which have almost entirely removed the evil. The needle inside the coil deflected by the working current is not a permanent magnet, but a piece of soft iron temporarily magnetized by the influence of permanent magnets outside the coil; but even these external magnets are sometimes demagnetized. Clouds are not perfect conductors, and, therefore, they do not part with all of their discharge at once. Hence a single discharge does not deprive a cloud of the whole of its charge. There may be several successive discharges. The electroscope and galvanometer show this. A clap of thunder is usually preceded by three or four powerful currents, and I have seen the letter R and C frequently made on the needle instrument. On the Morse apparatus they either produce rapid dots or cause the letters of a message to run together.

## III.—PROTECTION.

I will now discuss the measures that have been adopted for protection from this destructive force.

1. As regards ships, the method adopted by the great authority, Sir William Snow Harris, has proved itself to be so efficient and perfect that no improvement has been required; nor can any be well suggested. Accidents to shipping have almost entirely disappeared; fishing-smacks and small coasting ships are occasionally injured, but we never hear of an accident to the ships of our navy, or rarely to those of our merchant service. Such vessels as have been struck, have been invariably unprotected.

2. In the case of buildings, however, there is much room for improvement, not only in the form of the conductor used, but in the extension of its adoption. The heavy cost of a system similar to that used for our ships, has probably had a serious influence in checking

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the employment of such protectors. I have known men pay from £40 to £50 for protecting their houses; but, as I contend, most unnecessary expense has been incurred in such cases. I hope to show that it is possible for a man to render his house as absolutely safe as a ship has been made, at an expense which may be considered trifling.

It must not be forgotten that a chimney lined with a thick layer of soot, up which a current of heated air and volumes of smoke are ascending and terminated with a mass of metal (the grate) is an excellent but dangerous conductor, for it ends in the room and not in the earth. Hence so many indoor accidents, and hence the duty of every householder, particularly in exposed positions, to protect himself and his family.

The conditions that determine a perfect lightning protector are:—

That it shall expose in some prominent position of a building a metallic point, and that it shall offer from this point to the earth a path of little or no resistance to the passage of the current. Hitherto, in accordance with the directions of Sir William Snow Harris in his application to ships, heavy copper rods, ropes or plates of great expense, have been used; but I contend that a wire equivalent to the ordinary galvanized iron wire, known as No. 4, which is one-quarter of an inch in diameter, and used so largely for telegraphic purposes, is amply sufficient for any dwelling-house. The use of such an immense conductor is as though a man built a tunnelled sewer, where a small drain-pipe would do. My reasons for recommending telegraphic wire are these—when telegraph poles were first erected in this country, they were protected with lightning conductors made of No. 8 wire, led into a groove in the pole, and terminated at its upper extremity by a point. This practice was subsequently found to be expensive, and it was thought to be unnecessary. It was, therefore, abandoned, but at a later period it appeared that these earth wires or conductors were found to effect a very marked improvement in the working of circuits by removing the contact that occurred in wet weather between two contiguous wires. They caused the leakage from each wire to pass harmlessly to earth. Hence it is that on all our trunk lines, poles are invariably supplied with these earth wires—not as a protection from lightning—but as a means of removing the disturbing contact that arises on badly insulated lines during wet weather. Now it is a fact worth recording that a case of a pole so protected being damaged during a thunder storm is not on

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record; whereas unprotected poles are occasionally shattered to pieces. On examining a line of poles that extended from Basingstoke to Andover upon the London and South Western Railway system, fifteen per cent. of the poles were found to have been so struck. This line was renewed, and earth-wired, and since then not one single case of damage has occurred, although many years have elapsed.

Several poles have recently been discovered which were considerably shattered for the first few inches of their tops, but from the point, whence the wire proceeded to the earth, the poles were found to be thoroughly intact, the charge from that point passing harmlessly to earth through the wire. The cross-arms which are used for the support of the insulators and wires, are frequently found to be damaged as far as the earth wire, never beyond. Indeed, cases can be multiplied ad infinitum, where the No. 8 wire has been found sufficient to carry off the discharge harmlessly to earth. Moreover these wires unquestionably act as lightning protectors, for upon those lines which have been earth wired, the damage to apparatus has been small in proportion to those which occurred on lines not so protected. Hence I consider that I am justified in saying that No. 4 wire which is twice as massive, and offers half the resistance, is amply sufficient for the protection of such buildings as do not very greatly exceed our poles in height. I refer more particularly to dwelling-houses. However, as the height of buildings increases, and as we attain such heights as those reached by tall chimneys, and church spires, larger wire than this would be advisable. Stranded wire from its greater pliability is preferable to solid wire. I can conceive no case where ½-inch stranded galvanized iron wire is not ample.*

The following precautions are necessary in fixing conductors to houses:—

*a.* The conductor must be solid and continuous from its gilded or platinized point to the ground, *i.e.*, there should be no joint unless it be a well soldered one in the whole of its path. Chains and link rods,† which were used in the earliest forms of conductors should be

* A ½-inch rod, 46 feet long, conveyed harmlessly a charge, that destroyed the handsome spire of St. Martin's-in-the-Fields.

† At Monmouth I found a flat braided copper wire rope used about one inch broad. Its continuity is very doubtful. It had points at every 4 or 5 feet standing at right angles to the rope.

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strenuously avoided, and, where existing, at once removed. Indeed, every investigation has shown that where damage has occurred to buildings protected by so called lightning conductors, chains, linked, rods, or other imperfect conductors have invariably been used.

*b.* Its connection with the ground must be sound and good: in fact in the language of the telegraphist, "it must make a '*good* earth.'"

It may be connected with the iron gas or water mains; or be buried several feet in coke, or attached to metal buried in moist earth, or be carried down a well.*

*c.* Each conductor—if there be more than one—should make a separate earth if possible, and they should be all connected together, either above or below the surface. The lead roofing and all masses of metal in the line of probable discharge should be connected with them. They should be periodically examined, not only to see that their points remain intact; but that the metallic continuity is perfect, and that they continue to make a good earth. The only effectual test of such perfection is to be made by testing their continuity with the galvanometer and current to see that they offer no resistance. The custom now is to fix them, and then to leave them to chance! They are never examined. An instance has been brought to my notice in the Island of Jersey, where the lightning protector of a church was found to be broken off at a distance of two feet from the ground, and had been so for years; and the celebrated statue of Scott, in Edinburgh, was seriously damaged, owing to some mischievous person having removed the part which made connection with the ground, out of its receptacle. The practice adopted by many people to insulate these conductors, is evidently unnecessary, and it is equally absurd to carry them externally to their disfigurement—in the case of church spires, columns, and chimneys. It is, however, better to carry the wire externally in the case of dwelling-houses, least they pass too near to the lead gas pipes, which being themselves good conductors and soft metal, might be fused.

It is also assumed by some that electricity objects to go round a corner; and it is therefore urged that corners should be avoided; but it is evident, from the known laws of electricity, that this is an unnecessary restriction. The only point which one has to guard against is that there shall be no points or acute angles in the conductor,

* At Lydney Church (Monmouthshire) I found a lightning conductor of iron gas tubing

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lest branch circuits be determined; hence the straighter and more direct its course to the earth the better.

The area protected by the conductor is a matter of much consequence, and it was said by a committee of the French Academy that this area should have a radius equal to twice the height of the conductor from the ground; but cases have occurred, owing to the bifurcation of the discharge, where buildings have been injured at a distance considerably less than this from a conductor. Hence it is thought safer to take the radius as equal to the height of the conductor. Thus, for small houses one conductor is enough, but it is safer to attach one to each stack of chimneys. If it project a yard beyond, it is sufficient, for then it is within easy reach of inspection, a matter of some consequence when the principal function of the conductor depends, as I hope to show, upon the point with which it is surmounted being kept intact. Many houses, indeed most private dwellings, are already partially provided with conductors in the lead roofing and iron stack pipes that descend to the drains. It requires but little additional expense to make them thoroughly so.

It is thought that with 30s. for materials and 10s. for labour, any intelligent man can, with these directions and precautions, safely protect his house from the destructive effect of thunder storms.

I have recently had the pleasure of inspecting a plan adopted by Mr. W. H. Hyett, of Painswick House, near Stroud, Gloucestershire, by which he has succeeded in converting a two-inch wrought iron pipe, used for the ventilation of the drains of his house, into a very effective lightning conductor. The wrought iron pipe is carried from beneath the ground to a point eight feet above the top of the highest chimney. It is there surmounted with a vane having a sharp point some inches above its centre, the vane and the point being of copper. It is also connected with the lead coating of the roof. It appears to me to be an excellent and admirable system, worthy of greater adoption.

3. We will now consider the methods adopted to protect our Telegraphs.

I have already pointed out that the system of earth-wiring poles has given us an excellent protector, but in addition to this most of our large stations are approached by gutta percha wires in iron pipes underground, which form admirable lightning protectors, but, sometimes, at the expense of the insulating covering. Hence the apparatus at our large stations very rarely suffer from injury.

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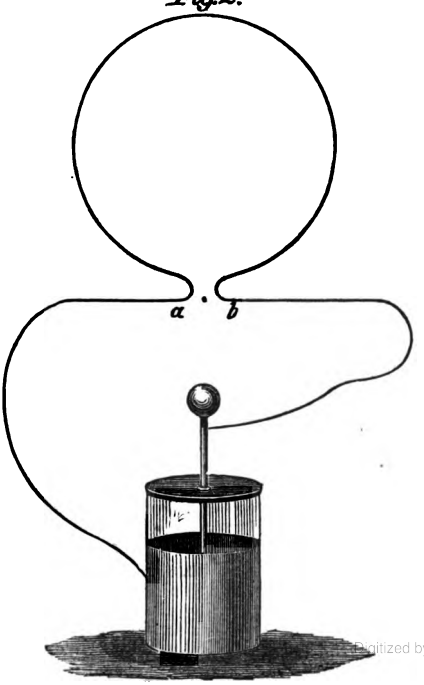
There are only two forms of lightning conductors introduced into the instruments adopted by the Postal Department. The one applied to the Single Needle and Morse apparatus, and the other to the Wheatstone's Alphabetical Instruments.

It was observed that when wires were knotted or tied together, electricity of high potential was discharged across this knot in preference to going through the loop. When a discharge takes place through a non-conductor, such as dry air, at the moment of discharge, the resistance along the line of discharge is so far reduced as to allow the passage of the greater part, if not the whole, of the current, so that, in point of fact, at the moment when the discharge occurs, through a layer of air or other elastic medium, a conductor of very low resistance is formed. Hence, as a current divides itself in inverse ratio to the resistance opposed to it, the greater portion, if not all, flies across the knot or shunt. This is only an example of Faraday's well-known experiment in which a long wire is so bent that two parts, *a b*, near its extremities, approach within a short distance, say a quarter of an inch in air. If the discharge of a Leyden jar be sent through such a wire, by far the largest portion, if not the whole, of the

*Fig. 2.*

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electricity will pass as a spark across the air at the interval, and not by the metal.*

Mr. Cromwell Varley, in the old form of single needle coils, simply twisted together the two ends of the coil wire before they were attached to their proper terminals, and it was found that this acted as a very efficient protector, the charge flying across the short interval in the twist, in preference to going through the coil. In order to make this system more mechanical and general, two wires of different colour were laid together and placed around the barrel of a small box-wood reel and applied to the ends of the coil. The wires themselves were still further protected by being drawn through melted paraffin, as damp affected them so as to cause contact. These protectors only act at their own expense, for though they may save the coils from the first discharge, they are themselves destroyed. A succeeding discharge must infallibly destroy the apparatus. This is the method adopted up to very recently in the Needle and Morse Instruments, but it has been partially abandoned for that in use in the alphabetical dial instruments, which is known as "S. A. Varley's carbon or 'lightning bridge' protector." The wires of the coil are attached to the termination of two insulated pieces of brass fitted in a box-wood cover, the opposed ends of which are pointed and inserted $\frac{1}{20}$ of an inch apart, in a chamber filled with a mixture of carbon and non-conducting matter in a fine powder, the preparation of which remains a secret with the firm who conceived and supply the apparatus. This protector acts as a shunt,† which offers such a resistance compared with that of the coil, as to prevent any appreciable diminution in the strength of the working currents, but it is assumed that in the case of the discharges of atmospheric electricity the potential is so high as to overcome this resistance, and convert the bridge into a path for the discharge, in preference to the coil. They have sometimes caused inconvenience owing to their particles becoming polarized, and forming a conducting line of low resistance, and thereby practically placing the instruments in short circuit. This is

*1406. The ultimate effect is exactly as if a metallic wire had been put into the place of the discharging particles; and it does not seem impossible that the principles of action in both cases may hereafter prove to be the same.—*Faraday's Researches*, Series XII.

†Mr. S. A. Varley says:—"Practically no electricity would pass from a fifty cell Daniell's battery through loose powdered black lead or wood charcoal; but a current of 200 or 300 cells would arrange the conducting particles by electric attraction and freely pass over; while a current of 600 cells would pass across a considerable interval of the ordinary dust t with in rooms, consisting chiefly of silica, alumina, and more or less carbonaceous and ty matter."—*British Association.*

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remedied by simply shaking, but it certainly is a defect of this form of apparatus.

Experience has shown that this carbon protector is not very efficient, and it is questionable how far it is based on correct principles. The chamber being filled with a partially conducting substance, prevents the peculiar action of the discharge through a gaseous medium which I have endeavoured to explain above.

The Postal Telegraph Department has greatly increased the number of instruments employed in this country. The number of stations have increased from 2,932 to 5,174, the number of instruments from 2,175 to 8,500. Its extensions have been erected into districts hitherto unoccupied by telegraphs. The area of the telegraphs exposed to the influences of atmospheric electricity has thus become greatly enlarged, and consequently the damage has assumed more formidable proportions.

The past year was exceptional to a degree, both as regards the number and violence of thunder-storms, but it has shown us that we must provide against such exceptional conditions.

The Telegraph Companies who at first used protectors, very soon abandoned them, and scarcely any were employed at the transfer. The Post Office wisely reintroduced them, but with great caution, not desiring suddenly to create a large expenditure in a precaution hitherto considered unnecessary, nor willing to incur too great a risk of interruption of communication from accidental injury to the protective apparatus itself, for it must be admitted that the more efficient the apparatus in warding off damage from lightning, the more apt it is to be put out of order itself accidentally. It is, in fact, desirable under the conditions of the Postal Service to sacrifice something of efficiency to safety from accident. The experience of the past year has shown that the line may have been drawn too near the limit of safety, but this is a matter which may safely be left to the responsible officers of the department.

We have been more successful with our submarine cables, which are protected with another very ingenious form of lightning protector, also from the prolific house of "Varley." In this instrument an earth wire, and the line wires are fused into a glass globe, which has been made a partial vacuum, and which, as is well known, offers a ready path for the discharge of electricity of high potential.

The discharge of electricity across air, depends not only upon the

distance which separates the opposite points, but upon the density of the air. The closer the air approaches a vacuum the less its resistance. Hence the efficiency of this "vacuum" protector.

They have frequently acted with great efficiency, and have given great satisfaction.*

In some of our cable huts an additional security is obtained by inserting a spiral of fine platinum wire of two or three feet in length between the line and the protector, and even this has been supplemented by the insertion of a form of protector in which a flat brass earth plate is separated from another plate in connection with the line, by a thin slip of parafined paper. The latter has also proved itself to be a very efficient form of conductor, and on examination, it is frequently found that the paper is pierced with small holes, giving the indication of carbonisation, an evident proof of their having been effective in drawing charges from the wire, and passing them harmlessly to earth. The paper in itself offers an almost infinite resistance to the passage of the working currents, but the air in its interstices is easily overcome by the high potential of atmospheric discharges. It is thus impossible for the wire of the cable itself to be raised to so high a potential as to endanger the dielectric coating until all three protectors fail to act. There has not been a case of a cable so protected breaking down, while there are cases on record of unprotected cables being injured.

It must not be forgotten that, as has already been observed, however valuable lightning conductors may be as protectors to our apparatus, they also produce numerous faults of their own. Thus, during the past year no less than five faults have been brought to my own knowledge, produced in the very few cable conductors under my charge. If their use becomes more general, the faults they produce must increase, so that in remedying one evil we generate another.

In India where the thunder storms are far more intense than in this country, and where scarcely a day elapses, during certain seasons, without the occurrence of lightning, very efficient means of protection have been adopted. Accidents are very rare. Every office is protected with earth plates, separated from line plates by a thin

* At Talybont, on the Anglesey shore, on July 7th, 1872, one of the Manchester-Dublin wires was found to earth, owing to an electric discharge having fused together the two points (line and earth) of a vacuum protector, and burst the glass globe. In detaching the wires from the box they came apart. The cable was undoubtedly saved.

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layer of air, the interval being maintained by thin ebonite washers. The line plate is sometimes studded with points secured into it, and the line wire is connected to it through a small coil of platinum wire. The posts also, when not of iron, are for a mile on each side of an office protected with rods projecting above their tops. When iron posts are used, this protection is not needed.

The effects of atmospheric electricity in America are well illustrated by the following extract:—"During a recent storm at Cincinnati, Ohio, the lightning followed the wires into the office, and at each flash concentrated in a sheet of flame on the switch board, producing a concussion similar, at first, to the discharge of a score of rockets, quickly followed by two reports as loud and distinct as the discharge of a six-pound cannon, succeeded in turn by a volley of musketry. It became necessary to disconnect all the wires, and keep them disconnected about an hour and a half. Some of the operators, who were unused to such severe electric displays, supposed at first that the 'day of reckoning' had come."

## IV.—Prevention.

I have lastly to speak of the prevention of lightning discharge. I have shown that electric discharge is simply due to the fact of two points separated by air, being raised to such a difference of potential that the resistance of the air cannot restrain their neutralization across it. Now if we prevent the increase of potential by dissipating the charge as it collects, we effect this object. This is the function of *points*. Points prevent the accumulation of charge. A pointed body, such as a needle, directed towards a charged conductor, dissipates the charge at once. A pointed conductor directed towards a charged cloud, dissipates the charge in its immediate neighbourhood quietly and silently. If lightning is seen to play about the top of a conductor it is a proof that it is out of order, and does not act properly. A glow or brush may be seen, but nothing more should be visible. Thus it is that the chief merit of a lightning conductor consists in the action of its pointed end, and hence the greater care should be taken to see that its point is maintained intact. Points are sometimes fused by powerful discharges. A properly constructed conductor may be said to prevent electric discharge within the sphere of its action. But it does not prevent thunder and lightning. When we consider the distance of the cloud and the area of its surface, the

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height of a building vanishes in the general figure. Hence the discharge may occur very near, though not within its protected area.

Since the potential of the atmosphere increases as we ascend, and we place at the top, say of the spire of a cathedral a pointed rod, we connect two points, the earth and the atmosphere of different potentials by a conductor. The result must be a current. This current constantly flows in one direction. Its strength will vary with the potential of the atmosphere. The result must be at the point of juncture with the ground, electrolytic action, and destruction of the conductor. I went to Llandaff Cathedral to test this theory. The conductor is a small copper stranded wire fixed externally by galvanized iron wall eyes. I took hold of it with my hand, and it came out of the ground most readily. It was entirely corroded at about a foot below the surface. The strands of the copper wire were eaten away to fine needle points, in a way with which submarine cable engineers are fully acquainted. It was bright and clean, indicating clearly the passage of a current. Here is a fresh source of danger, but it is mitigated, if not cured, by making earth with as large a mass of metal as possible, such as the gas or water system of a town. The electrolytic action is thus spread over such a surface that its effect is infinitely small.*

Lightning conductors, however, of all kinds require periodical examination. They will not last for ever. Their points should be maintained bright and clean, their electrical continuity should be kept perfect, their joints should be sound, and their earths should be good. If any of these points be neglected, the conductor fails to do its duty, and accident is the result. One of the brightest seeds of scientific thought is thus by ignorance and neglect allowed to fall into desuetude, and that which was erected for our protection may become a source of danger.

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## APPENDIX.

448, West Strand,
*June 5th*, 1854.

"Dear Sir,—We have had 'express' (underground wire) needles demagnetized and underground tunnel circuits fused during the last week."

* In many cases the copper wire is fixed to the masonry by galvanized iron wall eyes. If the stone be wet we have the conditions for a current, viz., zinc, water, copper. Hence, other element of decay, and another argument in favour of using galvanized iron wire,

The foregoing is an extract from a letter from one of our Superintendents, dated 1st June. It seems a very strange fact, but I have no doubt of its truth. I attribute it to the inductive effect of lightning in the vicinity of our underground circuits. The London and North Western is the district referred to.

Yours very truly,
(Signed) LATIMER CLARK.

Professor Faraday.

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Royal Institution.
*June 6th*, 1854.

My dear Sir,—I am very greatly obliged by your most interesting note. The fact is very interesting. You attribute it to the inductive action of lightning, and I suppose lightning must have been the cause of it. Do you not think it possible that the lightning has actually *struck on to the metal tubes* in the earth containing the wires, which would serve as lightning conductors to the flash, and that they may have induced at the moment on the wires within, or may even have divided the flash with them.

I am, my Dear Sir,
Yours very truly,
M. FARADAY.

Latimer Clark, Esq.

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Manchester Station,
*June 12th*, 1854.

L. CLARK, Esq.,

I thank you for the perusal of Faraday's letter, which I here enclose.

There can be no doubt that "Express" needles are de-magnetized by a *foreign current*. A slight explosion occurred at one of the Liverpool "Express" institutions. The coils were fused at one end of Huddersfield tunnel. The wires are percha, clipped to wood on tunnel walls, except where exposed to light, and then underground as also at the ends. The express wires are in *bands* for a considerable distance.

I fancy if the pipes or bands had been struck by lightning the percha would have been torn, and an earth or contact would have

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arisen. The tarred wires in lead pipes were often put in contact by lightning, or at least no other cause could be found.

During auroras our "deflections" show that the wires divide with the earth currents flowing between the points where the "earth" connections are made, and it is possible that in the greater electrical storms, currents may pass from point to point of the earth, and may last too short a time to move a needle, though they might ring a bell.

It is more likely that a neighbouring cloud induces a charge in the earth, and in our wires.

Yours truly,

(Signed) R. S. Culley.

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## MANCHESTER AND LIVERPOOL UNDERGROUND WIRES.

On the 4th July, one of my jointers reported to me that, during a thunderstorm on that day, whilst engaged in making the usual joints, he was disturbed and alarmed by some of the wires which were copper-jointed only, giving off sparks to his jointer's box which at the time was resting on the ground.

Himself and assistant were sitting on low stools on the ground level, with their feet in the hole, about 2 feet below the level, making joints in the wires which terminated in the boxes at every 400 yards.

The different ends of the wires were in the first place on the side opposite to the jointer's box; as each wire had its conductor jointed, it was passed over and rested against the box; on the completion of the whole of the conductor joints, the insulating joint was commenced, and when completed was passed back again to the original side. When the sparks were noticed, about one-half of the wires were properly jointed, the remainder having their copper joints resting very close to the box.

There were fourteen wires in all, joined up into a considerable length, and all the ends insulated except at this box and the next box to it (where jointing was going on). There was, therefore, no chance of any direct action from the lightning; the cause of these sparks must undoubtedly have been "inductive." This was the only time such an occurrence was brought to my attention, but on one occasion one man was seriously injured by being struck by lightning. He was sitting opposite a jointer in a box similar to the two I have

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described, when he was suddenly struck a violent blow across the shoulders, and so much hurt that he was unable to resume work for some days. The man who sat opposite him was untouched, but stated that, when it happened, his assistant was in a "blaze of light." I was very careful after that time about allowing the men to joint in thunderstorms.

August, 1871. GEO. E. PREECE.

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## DISCUSSION ON THE PAPER.

Mr. W. H. PREECE said the average number of protecting instruments which had failed this season was about 11 per cent.

Professor ABEL, F.R.S. (rising on the President's invitation), said he had been greatly interested in listening to Mr. Preece's paper. He was very pleased to hear several good practical suggestions in connection with lightning conductors, especially those which relate to the simplification of them; for having had considerable experience with regard to conductors applied to powder magazines, he had been frequently astonished at the vast amount of complication introduced. He had occasion to inspect a magazine in course of construction in the north of England not long ago—small wooden sheds, in fact, which contained no very large quantity of explosive material—and they were encased in broad thick slips of the purest description of copper. No doubt those conductors were expensive, and if their deficiency was in proportion to the expense, these buildings were thoroughly protected. He fully agreed with Mr. Preece as to the use of galvanised iron wire for conductors, and the importance of a thoroughly good, permanent earth.

With regard to what Mr. Preece said of the effects of induced atmospheric currents, one of the greatest difficulties in the application of submarine and earth mines was that of avoiding the sudden explosion of the mines through induced currents by the atmosphere or by electricity in a high state of tension. The Baron Von Ebner was the first to apply himself to this subject, and he was the first to notice the difficulty resulting from the development of powerful induced currents by atmospheric discharges in electrical cables. A striking in-

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stance of this was afforded in the defence of Venice and Pola, in the explosion of mines from the development of induced currents in the mines. Their experience had led them to abandon instruments of high electrical tension, as a means of exploding submarine mines and torpedoes. By the use of Siemens' Dynamo-Electric Machine, which worked more or less rapidly, they could generally guard against accidental explosions of this kind: and in the employment of frictional electrical machines it was noticed that running the wires together for two or three feet, even on the ground, was sufficient to cause discharge of mines by induced currents.

Captain Douglas Galton, C.B., F.R.S., said he had listened with very great interest to Mr. Preece's paper, more particularly in its bearing upon the lightning conductors applied to houses and buildings. He might mention, in corroboration of what Professor Abel had said, that last year, in consequence of the several severe thunderstorms, some persons applied to him on the subject of protecting the Public Record Office in London, which was a new building, consisting of a central tower and two wings. It was proposed to expend £300 or £400 in placing bands of copper to every pinnacle and chimney; to connect them horizontally together, and carry copper bands to the ground. He was not prepared to go to that expense, and he was glad Mr. Preece had shown it to be unnecessary.

There was one point in all conductors in houses which ought to be carefully attended to: that was that they should be carefully examined from time to time. One point of great interest mentioned by Mr. Preece was the fact of the chimneys and fire-places forming conductors, and the want of their connection with a good earth was the cause of many accidents. He had known several instances of that kind.

Mr. G. J. Symons said that, as a meteorologist, he had been very much interested in what he had heard from Mr. Preece this evening.

With regard to ball lightning. Some years ago he gave a lecture on lightning with respect to its meteorological effects, and expressed his belief in ball lightning: after the lecture several persons said there was no such thing, it was simply an hallucination.

With respect to bifurcation, he was acquainted with a case in point. Ten doors from his present residence a house was struck by lightning seven years ago, and a person who saw the flash come down described it as a ball of fire, about a foot in diameter, which after striking some

chimney pots, broke into three parts, one disappeared, one went along the gutter, and the other darted to the ground. He went carefully over the house, and it was evident that the flash had gone in two directions. It had taken the usual course down the chimney, to the fire place, and scattered the coals; but besides that it had gone along the water pipes, along the gutters partly full of water. Where there was any water no damage was produced, but where the gutters had no water in them the plaster inside was knocked down. Thence it went to the gas, which it lighted, and thence to the bell wires, which it dissipated. There was no question as to its being a case of bifurcation, and that in a very limited area.

With respect to intensity, Mr. Preece said a ship was liable to receive a more powerful discharge than a church or a house, and *à fortiori* still more so than human beings. It struck him as being possible that the reason why the bodies of persons who had been killed by lightning were so very differently affected might be due to difference in the intensity of the discharge.

The fact of the telegraph poles being shivered in the way described was, to a certain extent, contradictory of the explanation given as to the cause of trees being burst by lightning. He had understood that the heat generated by the flash of lightning passing through the tree converted the sap in it into high pressure steam, which burst the tree open: but there was no sap in telegraph poles to cause the same results, and, therefore, the bursting showed it must be rather due to the repulsion of the different particles of the wood, and not to steam. Mention had been made of what Dr. Franklin had spoken of as cold fusion. Was there such a thing or not? There were a great many cases in which persons struck by lightning had a steel watch-guard and a watch in their pocket: the whole of the works and sometimes the case were partially fused, and yet the clothing had not been singed. That was a puzzle to him.

Another point to be noticed was that which some years ago was much debated, but which he gathered was now settled. He referred to the controversy which took place as to the relative advantages of terminating a lightning conductor with a sharp point, or a ball or blunt end. The argument of those who said a sharp point was of no consequence was this—that, compared with the area of a cloud which might be two miles, the bluntest rod they could put up was a point. From Mr. Preece's remarks, and especially as he said the point should

be gilt or platinum, and kept clean and bright, he gathered that gentleman considered the point was extremely desirable. He (Mr. Symons) was of the same opinion, but it upset the old theory that in consequence of the magnitude of the cloud area, point or no point was a matter of no moment.

The further discussion on the Paper was adjourned until Wednesday, the 11th December.

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The Meeting then became a General Meeting.

The following alterations of the Rules and Regulations having been proposed by the President, were unanimously carried:—

RULE VI.—The officers of the Society shall be a *President*, the *Past Presidents*, four *Vice-Presidents*, and twelve other *Members*, who shall constitute the *Council*, to direct and manage the affairs of the Society; also, two Auditors of Accounts, a Treasurer, an Honorary Secretary, and a Secretary. Such officers shall be elected or appointed annually, in manner hereinafter directed.

RULE VII.—In addition to the above, three *Associates* shall be elected annually, to serve on the Council.

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*The following Candidates were balloted for and duly elected:—*

AS FOREIGN MEMBERS:—

Charles Burton, Director-General of the Argentine Telegraphs, Buenos Ayres.

Professor D. E. Hughes, Paris.

L. G. Tillotson, New York.

James Dakers, Montreal.

AS MEMBERS:—

E. Haviland Burke, M.P.

Edward Cripps, London, Brighton and South Coast Railway, London Bridge.

John D. Den, Cape of Good Hope.

William Ellis, Royal Observatory, Greenwich.

W. H. Floyd, Wellington, New Zealand.

M. Greenhill, Post Office Telegraphs, Belfast.

James Graves, Valentia, Ireland.

Frederick Haynes, Bristol and Exeter Railway, Taunton.

Captain Halpin, Great Eastern.

Sir Donald McLeod, C.B., K.C.S.I.

Dr. Lyon Playfair, C.B., 4, Queensbury Place, South Kensington.

Edward Rosenbusch, Valletta, Malta.

Captain Turner, R.E., Post Office Telegraphs, Ipswich.

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As Associates:—

John Aird, Jun., Southwark.
Francis Black, Post Office Telegraphs, Cork.
William Bottomley, Blackheath Hill.
J. Burke, India Government Telegraphs.
Frank Carlile, Post Office Telegraphs, Plymouth
Lawrence Collins, Post Office Telegraphs, Cork.
Duncan Cromartie, India Government Telegraphs.
John Dallas, Greenwich.
Francis Daniell, Indo-European Government Telegraphs.
Patrick Delany, Post Office Telegraphs, Dublin.
William Drury, Sen., Postal Telegraph Stores, Gloucester Road.
Henry F. Fisher, Singapore.
A. Le Neve Foster, Cairo, Egypt.
C. B. P. Gordon, India Government Telegraphs.
John Gott, St. Pierre, Newfoundland.
William P. Granville, 28, Hanover Street, Islington.
Walter Hall, Aldermanbury.
Albert B. Horner, General Post Office, London.
William Humphries, Post Office Telegraphs, Limerick.
Howard Jobson, Dudley.
W. P. Johnstone, India Government Telegraphs.
Thomas Lowe, Great Winchester Street Buildings.
Henry Pomeroy, Post Office Telegraphs, Waterford.
Captain W. Shaw, 73rd Regiment.
George Stephenson, Alexandria.
Wm. Tansley, Post Office Telegraphs, Portarlington.
Percy Tarbutt, The Avenue, Streatham.
H. E. Thompson, India Government Telegraphs, Alipore.
W. J. Tyler, 100, Cannon Street.

The Meeting then adjourned until Wednesday, the 11th December.

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The First Annual and Eighth Ordinary General Meeting was held on Wednesday, the 11th December, 1872, Mr. C. W. SIEMENS, F.R.S., LL.D., President, in the Chair.

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The Discussion on Mr. W. H. PREECE's Paper, on "Lightning and Lightning Conductors," was resumed by

Mr. W. E. AYRTON who said, the ordinary law for the flow of an electric current through two alternative circuits was, of course, that the current divided itself inversely as the resistance. This law he believed to be true in all cases, with this peculiarity, that for electricity of high potential a thin stratum of air had less resistance than a long thin wire. On this principle the majority of the lightning protectors for telegraph lines are constructed, among which, as far as his experience in India went, the best he thought was the "Plate Discharger" of Dr. Werner Siemens. The two metal plates of which this discharger consists are connected one with the line, and the other with the earth, and are placed close together above one another, but prevented from touching by the insertion of ebonite washers. Each plate is chiselled in grooves and ridges, the ridges being parallel to one another, and the plates are placed so that the ridges of one plate are at right angles to the ridges of the other, then, since the intersection of ridges are points the apparatus is equivalent to a very large number of points in connection with the line opposed to a very large number of points in connection with the earth. This instrument, besides being very easily cleaned and so causing practically no leakage of the working current, is not necessarily damaged by the discharge of a lightning current, as is generally, as far as his experience went, the next best form of lightning protector, Mr. Varley's Vacuum Discharger.

Weak currents, such as are used for signalling, pass through the instrument at the end of the line, and do not at all escape at the lightning discharger. Much stronger currents, on the other hand, such as are produced by a violent discharge of atmospheric electricity, do not pass at all through the instrument, but escape altogether in the form of a spark from the upper to the lower plate of the lightning

discharger. Between these two, however, there must be many currents of atmospheric electricity which do not charge the upper plate of the lightning discharger to what might be called a "sparking potential," but which are quite strong enough and which last for a sufficiently appreciable time to damage the instrument. For the heat developed in a time ($t$) is given in thermal units by the well-known formula—

$$\frac{V^2 t}{R J}$$

Where V is the potential to which the upper plate, or plate connected with the line, of the lightning discharger is raised; $t$ is the time during which it is raised to that potential; R, the resistance of the instrument; J, Joule's equivalent.

Now V may be much smaller than the "sparking potential;" still, if $t$ be sufficiently large, the product—

$$\frac{V^2 t}{R J}$$

may represent quite sufficient heat to damage the instrument. Of course ($t$) must not be taken so large that any heat is lost by dissipation. This consideration might, he thought, explain the curious cases that now and then happen of instruments being destroyed without the lightning discharger having apparently acted.

A common precaution taken in telegraph offices is that of introducing a piece of fine platinum wire in circuit between the lightning discharger and the instrument, on the supposition that this piece of wire will be fused before the instrument is damaged, and so the instrument cut off from the line and saved from any injury. This arrangement, he thought, would not be of much practical use for *violent* discharges, because such discharges would probably escape to earth at the lightning protector, or, as he should presently show, possibly even before reaching the lightning protector, and would not pass through the fine wire at all. For weaker currents, however, which were not strong enough to raise the lightning discharger to a sparking potential, but which were of sufficient strength, and which lasted for a sufficiently long time to damage the instrument, he thought the insertion of the fine wire might be of use in saving the instrument. If, however, the fine wire is of use in such cases, the following arrangement would apparently be much better:—A galvanoscope wound with very thick wire, and having a highly magnetised needle, which,

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therefore, oscillates very quickly, is placed between the ordinary lightning discharger and the receiving instrument. The axis of the needle is electrically joined with the terminal by which the galvanoscope is connected with the receiving instrument, and a stop on the face of the dial used to limit the motion of the needle is connected with the earth. The ordinary working currents do not, of course, affect the galvanoscope. Atmospheric discharges of high potential escape at the lightning discharger, and also do not affect the galvanoscope. Currents of immediate strength, however, which are not strong enough to raise the lightning discharger to a sparking potential, but which are strong enough to damage the instrument if allowed to pass through it for any appreciable time, are cut off after passing through the instrument for an *exceedingly short* time, by causing the needle to touch the stop. At the cessation of this atmospheric current, the needle returns to its original position, and the line is again fit for working. This arrangement possesses all the advantages of the fine wire, and has this additional advantage, that it causes no permanent interruption in the line, as, of course, does the fusing of the fine wire. If, as is sometimes stated (a statement which he did not think to be true in all cases), atmospheric currents take *no time*, and, therefore, the instrument would be destroyed before the needle could touch the stop, then it must also be objected that the piece of fine wire commonly inserted in the line can be of no use, as the instrument would be damaged before the fine wire is fused.

When the atmospheric discharge has a much higher potential than have the discharges he had at present been dealing with, it will pass neither through the instrument nor the lightning protector, but will jump from the line wire to the insulator stalks, if they be connected with the earth, smashing the insulators in its path. An instance of this phenomenon he remembered seeing in India, in a telegraph office in a suburb of Calcutta, during a rather severe Indian storm. After a bright flash and a sharp report, the line to Calcutta was reported interrupted, without the signaller seeing or hearing any evidence of a discharge of electricity at the lightning protector which was on the table by his side. He (Mr. Ayrton) tested the relay of the instrument, and found that it was not at all damaged, but on examining the line just outside the office it was found that about fifteen insulators on successive posts were smashed, the porcelain in many cases being broken in concentric rings. The line wire which had been tied to the top of

the insulators had fallen down on the iron brackets in connection with the earth, or on to the iron insulator stalks, which remained standing in their places in the brackets, but from which the porcelain had been broken away.

The majority of the insulators in India have attached to them iron hoods or caps, and the edge of the hood is, in most cases, not very far from the iron bracket which is fixed to the iron post planted in the ground. If, therefore, the line wire and iron hood in connection with it be charged to a very high potential, a discharge will take place from the edge of the hood to the bracket without necessarily breaking the insulator. This arrangement forms probably a considerable protection against damage to insulators by atmospheric discharges of very high potential, and is, therefore, an argument for continuing the use of this kind of insulator. The insulators which he had referred to as having been broken, were exceptional in not having this iron hood.

A further precaution has lately been taken thus: at the terminal post, or last post before the lines enter the office, there is attached to the hood of each insulator a brass ring, into which is screwed a pointed brass rod, which is adjusted so that the point of the rod is close to the iron post. During storms sparks are seen passing from this rod to the iron post. If this arrangement could be attached to all the posts, no insulators scarcely would be destroyed by lightning; the advantage, however, so gained would, of course, be more than compensated for by the loss of the signalling current, on account of the dirt that would collect between the brass point and the iron post.

There is another annoyance that is experienced in India. On all the lines, long and short (some of the short lines would be long for this country) Mr. Siemen's Polarized Relay is used, which consists, as most of those present know, of a permanent angular magnet, attached at one end to a steel tongue, which is magnetised, therefore, with one polarity, and at the other end to the two metal cores of a horse-shoe electro magnet, which are, therefore, kept permanently magnetised with the opposite polarity. The metal tongue placed between the two cores, is attracted, therefore, by both of them, and consequently tends to approach the one it is nearer to, in doing which it presses against a small glass stop. The effect of the signalling current is to weaken the magnetism of the core that is nearer to the tongue, and to strengthen the magnetism of

the other core. This causes the tongue to leave the glass stop, and to move over to and press against a metal stop on the other side, by doing which the local circuit is completed. When the signalling current is broken the core that has been weakened becomes stronger again, and the core that has been strengthened becomes weaker again, in consequence of which the tongue leaves the metal stop and returns to its normal position against the glass stop, the local circuit being thus broken. If, however, the current that has been received is much stronger than that for which the relay is adjusted, then, on account of residual magnetism, the core that was strengthened by the current does not lose all its extra magnetism, and the core that has been weakened does not regain all its lost magnetism, the consequence of which is that the tongue does not return to its normal position, but remains pressing against the metal stop, continuing, therefore, to produce the signal after the current that originated it has been broken.

Now this continually happens in India during the monsoon, that is, during the stormy months of July, August, September and October. The signaller has perhaps received the first letter, or part of the first letter of a word, when an atmospheric current, not strong enough to injure the relay but still very much stronger than the working current, comes along the line. This causes the instrument to "stick," and while the signaller is re-adjusting his instrument, the word is finished without his having perhaps received a single letter of it. The same thing perhaps occurs over and over again, causing a most serious delay. No instrument had, as far as he knew, been devised which in the least prevented this inconvenience. Of course, any signal actually being produced when an atmospheric current comes along the line must necessarily be lost, on account of the superior strength of the latter current, but that the next thirty or forty signals should also be lost, is not an absolute physical necessity.

As the lines in India are supported on iron posts at a distance of about 80 yards apart, and to each of which is fitted a pointed lightning conductor the point of which is from a foot and a half to two feet above the line wire, it is not easy to see how the wires are "struck" at all, unless it be that the effect is produced by the induction of a rapidly-moving highly-charged cloud, or a stationary cloud of rapidly, varying potential, or, of course, a combination of the two. One would have imagined that the lightning conductors attached to all the iron

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posts would have completely protected the wires from being struck in the way a house, for instance, is struck.

Mr. CULLEY: Are the plate protectors perfectly efficient, or does it ever happen that instruments guarded by these protectors are fused?

Mr. AYRTON: They are occasionally fused; and the explanation may be that which I have given.

Mr. CULLEY: May I further ask whether these plate protectors ever accidentally interrupt the circuit by putting "earth" on?

Mr. AYRTON: Very rarely. By a late arrangement the plate protector is now put in between the commutator and the line. If there was an interruption it would be localised at once. Personally, I know of no instance of the plate protector interrupting the line.

Colonel ROBINSON, R.E., said the plate protectors were put into glass cases to prevent dirt collecting and making contact between the upper and lower plates.

Mr. W. T. ANSELL remarked that the Siemens' plate protector was extremely efficient. He remembered, in the Levant, two or three years ago, during a storm some plates were fused by the lightning, but they quite protected the cable from the effects of the lightning which struck the overground wires in connection with the cable. He never experienced an instance where the protectors were insufficient except where they were allowed to get dirty; but if, as Colonel Robinson said, they were closed in with glass, he knew of no more efficient lightning protector than this.

Mr. VON FISCHER TREUENFELD said, during the time of the Paraguayan War he had charge of the telegraph lines of that country. Circumstances connected with the war frequently made it necessary to work the field lines during very heavy tropical thunderstorms, and they had to risk the danger, not being able, under the circumstances, to put the lines to earth. He used Siemens' plate lightning dischargers, which were often fused during thunderstorms, but the instruments always remained uninjured.

Mr. G. G. NEWMAN said, there are a number of Varley's Carbon protectors fixed in instruments (Train-signal instruments generally) in use on the London and North-Western Railway. These protectors have, so far as we are able to judge, performed their office satisfactorily, but we have seven instances recorded where they failed to save the coils from fusion. They have also caused interruptions in

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two or three instances by short circuiting. We have a large number of instruments and bell-coils protected by the twisted wire arrangement, which has done good service, although the coils have not always escaped. On one occasion six of these twisted wire protectors were fired simultaneously, and the coils saved; in another instrument in the same office the twisted wires were completely melted, and the coils fused also. The Varley Bridge is, no doubt, the best in principle, but I think the twisted wires are equally as efficient as a protector, and they are cheaper, and can be readily replaced by clerks and linemen when damaged by storms. Varley's Bridge is a fixture in the instrument; and, if it gets out of order, cannot be replaced immediately. There is plenty of scope for improvement, and the protector of the future has yet to make its appearance.

The President having called upon Mr. Preece to give some additional explanations on that part of his paper which referred to ball lightning,

Mr. W. H. Preece said he alluded at the last meeting to one of the most difficult forms of lightning discharge, namely, that commonly called "ball lightning." Ball lightning had by many been considered a myth, and that by one, than whom there was no greater authority in the world—Faraday—who said there might be balls of lightning, but not of electricity. However, the evidences we possess of such phenomena are so numerous, that it was impossible to deny that ball lightning in some form does exist. Some have explained the phenomena by assuming that these balls of fire were incandescent gases, but one of the cleverest explanations was that given by Mr. Cromwell Varley, and of that explanation he (Mr. Preece) had drawn a diagram which assumed a state of things which, to a certain extent, explained that gentleman's ideas. Mr. Varley had repeated his experiment before them. He had shown by means of his electrical machine that it was possible by a little scheme of his with a piece of string attached to one pole to produce upon the sphere on the other pole what appeared to be a ball of lightning, and what Mr. Varley said was this, When we have a cloud negatively electrified, from the point of the cloud to the ground, we have a bunch or bundle, a series of lines of force, which are depicted by the red lines on the diagram, terminating in two points, one point being upon the cloud and one point upon the earth. When a cloud is negatively electrified the result is, that upon the

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earth we see what is apparently a ball of fire. These lines of force take a form similar to what is shown on the diagram, and these being elliptical, and concentrated upon the earth, give to the lightning the appearance of a ball of fire. As Mr. Varley's ball of string moved, and as the cloud moves, so does this apparent ball of fire follow the cloud. Then it comes, that assuming this cloud to be moving, the electrical lines of force will follow the cloud till it comes to some building or object which tends to reduce the resistance, and then this peculiar condition is broken through and lightning discharge takes place. Hence, in the instances of balls of fire that have been seen at sea, the masts of the ship form a part of the electrical lines of force, and the result is discharge. That, he believed, was in substance Mr. Varley's theory, and it appeared to be very sensible, but it involved this consideration, viz., that there shall be a negatively electric cloud. Now, fortunately, there was present this evening the greatest authority they possessed upon atmospheric electricity, and he would be glad to hear from Sir Wm. Thomson first, whether there was substantial evidence that clouds do exist in a negatively electrified state, and, secondly, whether in his opinion this explanation of ball lightning is consistent with our present knowledge of its effects?

Sir W. Thomson said: The subject of atmospheric electricity is yet in its infancy, and is one of extreme difficulty. Very few experiments, and until lately no regular set of accurate observations, have been made, so that at present it is impossible to give much definite information. In answer to Mr. Preece's question whether there are such things as negatively electrified clouds—The electrical condition of air, making no distinction as to its being cloud or not, is what is how generally observed. There is no way of ascertaining the electrification of clouds unless we get into them by ascending in a balloon, or by some other means. There is no reason to suppose that clouds are essential to electrical discharge in the atmosphere. On the contrary, instances are recorded, both in ancient and modern times, of lightning flashes occurring in a perfectly clear sky. Clear air generally is of as great importance as cloud, possibly in general of greater importance than cloud, in the theory of atmospheric electricity, and clouds must not be spoken of and studied to the exclusion of the rest of the atmosphere. The electric potential of any point in the air, can be measured relatively to the earth, without the slightest ambiguity. One of the

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methods of doing this is by means of a water dropping apparatus. This consists either of an insulated vessel from which a stream of water flows in the form of a fine jet, and breaks into drops at a definite point in the air, or of an insulated receiver in which drops from an uninsulated jet are collected. In either case the insulated part of the apparatus is put in metallic connexion with one electrode of an electrometer, the other electrode being connected with the earth. With the first arrangement, viz., the insulated vessel and jet; the potential measured on the electrometer is equal to and of the same sign as the potential, at the point where the jet of water breaks into drops. With the second arrangement, in which the drops of water are collected in an insulated receiver, the potential indicated on the electrometer is of opposite sign to that of the air at the jet, and goes on augmenting indefinitely. For ordinary observation the first method is uniformly preferable to the second. In both ways the electrification of the air in a room was tested after it had been charged by turning an electrical machine with a lighted spirit lamp standing on the prime conductor. The test was also applied in a room into which air was drawn from another room, in which an electric machine was worked, and from out of doors alternately. The difference in the electric conditions of these currents of air was very distinct. That which came in from out of doors, in fine weather, was generally found negative. I have learned from this and other unmistakeable experiments that the lower stratum of air is, in fine weather, in general negatively electrified. [Reprint of Papers on "Electrostatics and Magnetism," §§ 296—300, and § 392.] The potential of the air out of doors, in fine weather, is always, with but very rare exceptions, found to be positive. In showery or wet weather it is sometimes positive and sometimes negative, occasionally altering with extreme rapidity. As the lower portions of the atmosphere are, in fine weather, negatively electrified; if a large quantity of air spread out in a horizontal sheet—say about a quarter of a mile thick, and extending over an area of several square miles—were to be raised by a current, so as to form a vertical column, this would produce exactly the effect that a negatively electrified cloud or other body would do if placed over the earth at that point. The manner in which the change of form in the mass of air must take place is illustrated by the way in which a body of troops change form when, having been in the line, they get into column. Each

particle of air must be moved from the position it occupied in the horizontal layer to its proper place in the column, but always retaining the quantity of electricity with which it was originally charged.

To turn now to Mr. Preece's second question. Although the phenomenon of ball lightning, as it is usually described, is not in accordance with the known laws of electric discharge, yet there is, doubtless, some truth in the many wonderful stories that are told concerning it, and we will do well to try and find the explanation. In Mr. C. F. Varley's beautiful experiment, to which Mr. Preece referred, a bright spot of light, on a smooth metal plate, follows the motions of a point on the negative pole of a Holtz electrical machine. From this experiment there is still much to be learned, and it is probable it may, as suggested by Mr. Varley, illustrate the true cause of the actual phenomenon which has given rise to the idea of "ball lightning" as usually described. There is little doubt that if suitable precautions were taken, lines of light would be seen extending from the generating point on the negative pole to the bright spot on the positive one. The visible lines of electric flashes or sparks are, as it were, cracks in the air, quite as real as, and perfectly analogous to, the crack in a Leyden jar that has given way under too great a charge; but with this important difference, that the cracks in the air at once close up and are repaired whenever the electricity causing them has passed, while those in the glass remain, and can be examined. The generating point makes the opening or commencement of the crack, while the other end of it is seen on the polished metal of the positive pole. It seems reasonable to suppose that when one end of the crack is moved about, the whole crack should move, and, consequently, the other end where the bright spot appears because of the enormous resistance there is to the formation of a new crack in the air, and the comparatively great ease with which the crack is kept open by the passage of the electricity after it is once formed.

Mr. Latimer Clark said that fire balls were among the most interesting and mysterious of electrical phenomena. He had seen Mr. Varley's experiment, but was not prepared to say that to his mind it fully explained the phenomenon, but it was a beautiful experiment, and appeared to illustrate them on a small scale. No doubt some present had seen the notice in *The Times* of December 3rd, of a fire ball that recently fell at Banbury. He had placed himself in commu-

nication with the gentleman who wrote it, and he would read a short extract from Mr. Cartwright's letter :—

"I was leaving the house, my gardener called me to come quickly and see the ball of fire. I was, unfortunately, half a minute too late, but I have seen four persons who saw it from different points of view, and who all agree they heard a whizzing, roaring sound, like a passing train, which attracted their attention, and then saw a huge revolving ball of fire, travelling from six to ten feet off the ground. The smoke was whizzing round, and rising high into the air, and a blast of wind accompanying it, carrying a cloud of branches along, and destroying everything in its way. I rode, this afternoon, along the whole line of its journey, about two miles in length. Where it first began, the breadth of ground travelled over was very narrow, but increased as it proceeded, till, in the last field, the *débris* covered a space quite 150 yards wide, and here it seems to have exhausted itself, as all the witnesses agree that the ball of fire seemed to vanish at the spot without any explosion. Here the ground had been cut in places as if by a cannon ball; but I could find no cause for this, and I saw no signs of fire on its route. One man, however, says there was a strong sulphurous smell after it had passed."

This looked at first like one of those mysterious fire-balls so frequently mentioned in both old and modern writings. In a subsequent letter he had received from Mr. Cartwright, that gentleman said that the witnesses were less confident about the amount of fire, but they declared that they saw red flashes or sparks accompanying it. That was a very interesting point. It appeared evident from the description that this was a case of a whirlwind which descended from the clouds in the form of a ball, and traversed about two miles of ground, upsetting trees and doing other damage; and the statement of three persons was that in full daylight they saw sparks of fire accompanying the ball, and that they smelt a sulphurous smell, which was so usual an accompaniment of electrical discharge. It was possible that fire-balls might be sometimes produced by whirlwinds, though certainly not always so. There was recently published a letter from a gentleman in Birmingham, who stated that looking through a window he saw a ball of fire 2 or 3 feet in diameter fall in his yard, and after it had rebounded, it exploded at a height of about 10 feet from the ground without doing any damage. Now what could this be? it certainly could not be a whirlwind. He had not the advantage of being present at the last meeting, and therefore did not know the scope of the paper or the nature of the discussion which followed upon it, but on the subject of lightning dischargers he could mention a plan he had himself adopted, which he thought had some merit. The ordinary

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Siemens' discharger consisted of two flat plates, but he could not avoid feeling that points were better suited for dischargers than flat surfaces.

The President said the plate-conductor was in reality an infinite number of points, because one surface was planed with a pointed tool in one direction, and the other in the opposite direction, so that they, in reality, formed a plane of points.

Mr. Latimer Clark said the plan he had adopted was this—a thick metal plate was pierced with a number of holes, and pointed pins were dropped loosely into the holes, resting on a lower plate connected with the earth, with a thin sheet of tracing paper between them, so that each point was separated from the bottom earth plate by the thickness of the paper only. Perhaps the most efficient conductor he had seen was one in which flame was employed. It was the invention of a German gentleman, Dr. Hirz. A number of points were opposed to each other, and the flame of a spirit lamp was caused to burn between them. They were arranged within a cylinder, divided in two halves. They could not, of course, be used in offices generally, but one could afford to use them in protecting submarine cables during storms. He felt certain that the flame discharger would act well, because the resistance between the two sets of points was extremely small.

Mr. Preece in discussing the question of the minimum size of wire necessary to form lightning conductors instanced as a proof that there was no necessity to use thick wires, the fact that they never heard of telegraph poles being destroyed, though they were only connected with earth by No. 8 or No. 10 sized wire. He fully agreed with Mr. Preece that a comparatively small wire was sufficient to protect a house of ordinary height; but he did not think the fact Mr. Preece instanced was proof of that. When the lightning struck the poles or wires, it not only passed down the nearest pole, but it traversed the wires, and could by that means travel down a great many poles to earth. He believed that when lightning struck any object, it frequently divided into several distinct forks or channels. Those who had experimented with large electrical machines were familiar with the beautiful way in which the spark travelled whole for a certain distance, and then, if the receiving conductors were flat or arranged equidistantly, broke into forks. At his own residence a violent discharge of lightning recently struck the house, also a neighbouring

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lightning conductor on a building about the same height as the house, and also a beech-tree which stood near it. The lightning was seen to strike the conductors, and the beech-tree gave evidence of having been struck, inasmuch as a rake which was leaning against it was split into shreds, and the ivy growing round the tree was killed, and had its leaves around for a long distance. There was abundant proof that the lightning in that instance chose three different paths. He was of opinion with Mr. Preece that No. 4 wire would form an efficient protector for an ordinary house in cases where economy had to be studied, for he felt that even an insufficient conductor, if connected with the earth, would protect a house from injury, though it might itself be destroyed. He knew of no instance in this country in which No. 4 wire had been fused, except at the point where it passed into the air, and there it was a common thing for considerable masses of iron to be fused. He believed that well-built houses were generally protected from lightning by the lead water-pipes and ridges about them, and it was from that cause he thought they heard of so few accidents to well-built houses. He witnessed in 1869 in the Persian Gulf a most interesting electrical storm, of which he had made some memoranda at the time; and he would, with permission, read extracts from them.

"The first gale occurred on the 1st November, about nine o'clock at night, when about 130 miles from Bushire. The weather had for many days been settled and fine, with a high barometer and strong morning breezes, dying off in the afternoon to a dead calm. Distant lightning and dark heavy clouds were occasionally seen in the N.W. on the night in question, the sun had set as usual on a calm sea, and the cable was being paid out steadily from a large sailing vessel, the Calcutta, towed by a very powerful steamer, the Dacca, when suddenly, and without the smallest warning, both vessels were struck by a hurricane or blast of cold air, mixed with scattered rain, which brought them up standing as effectually as if they had run against a stone wall. For a few minutes a scene of great confusion followed. It was impossible to stand without holding on to some fixed object; awnings and windsails were carried away or had to be cut adrift, and loose articles of every kind were overthrown and hurled along the deck; the roar of the tempest was so loud that commands were inaudible; the steamer became unmanageable, being encumbered by a steam barge which she had in tow and had to cut adrift, and both she and the Calcutta presenting broadsides to the wind, were carried bodily leeward. After struggling ineffectually against the storm for an hour and a quarter, and losing a good deal of cable which was paid out in a backward direction, it was thought best to cut and buoy the cable; and the Dacca, having got up more steam, towed her consort in under the land for shelter. In the

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meantime, the thermometer had fallen nearly thirty degrees, and a tempest of thunder and lightning burst over the vessels on a scale of great grandeur and beauty, which, as the vessel's masts and riggings were all of iron, could be enjoyed without apprehension; the flashes averaged thirty or forty per minute, and the roll of thunder was incessant. Many of the flashes appeared to drop into the ocean perpendicularly as a single stream of fire, which enlarged at the point where it struck the water. From their distance and apparent height, many of these flashes were estimated to have fallen from a height of 1,000 feet. They were followed by rapid interchanges of electricity among the clouds above, as if the disturbed equilibrium were readjusting itself. Other flashes appeared to originate like the sources of a river, in a thousand separate streams, which, uniting together, joined into one apparent trunk and fell into the sea, presenting the appearance of what is called a genealogical tree. One flash in particular extended its branches out horizontally to a wider extent than the eye could take in, so that for an instant the whole visible heavens were filled with innumerable streams of fire, converging into a common trunk and descending into the water. All the flashes appeared to be double, and some were repeated three or four times, but at such rapid intervals that they could not be counted, but appeared as it were to flicker. Some flashes struck the "Calcutta," and, although only visible to those on board as a dazzling and blinding light, as viewed from the sister ship, the whole upper part of her masts and rigging were seen to be clothed with fire. Some few flashes were seen distinctly to rise out of the ocean and, striking straight upwards, to disperse themselves among the clouds. The lightning only lasted half an hour in its greatest intensity and then appeared to drift away with the storm to the S.E. The hurricane, after lasting two hours, changed into a gale from the E. and S.E., which by morning had subsided into a calm.

"The next day the cable was spliced up and paying out had scarcely recommenced with a strong S.E. wind, when notice was received that another violent storm from N.W. had passed Bushire, and was on its way down the gulf. Full steam was accordingly got up, awnings taken in, and every preparation made for its reception. At three o'clock, black clouds were seen rising, and at 3.52, the storm burst forth with the same suddenness and fury that characterised the previous one; being daylight, many phenomena were observed, which were missed the previous night. As the clouds approached they gathered into a peculiar form resembling the cap of a large mushroom, extending entirely across the heavens from one horizon to the other. The lower edge of the mushroom had a rounded and wrinkled margin, but was very sharply defined; the surface was composed of innumerable similar strata, as if melted pitch had been poured out and allowed to solidify in numerous cakes each rather smaller than the one below. Underneath all was a dark chaos, which soon enveloped the vessels, the wind still blowing aft. Suddenly there came a profound calm, and a few hundred yards a head, the squall was seen approaching. The sea was elsewhere covered with full sized waves, but under the influence of the hurricane it became one dead level of creamy foam, the top of every wave being swept off into spray as soon as it rose. Numerous small whirlwinds swept along

surface, carrying up waterspouts towards the clouds, and for a few moments the darkness and the breathless calm, contrasting with the threatening turmoil of the approaching squall, and the lurid light of the sky still gleaming behind formed a very impressive scene, which was heightened by the incessant roll of distant thunder. In another moment the squall struck the vessels with the same fury as on the previous occasions, and the thermometer fell at once from 81° to 53°; torrents of rain swept the decks, accompanied with continuous peals of thunder and lightning, and all the appearances of the previous night. The vessels, however, steamed ahead with full power, and were enabled to maintain their way successfully, losing, however, about four miles of cable. After about two hours, the sky grew bright, and the wind changed into a gale from the S.E., followed by a calm. One or two phenomena were noticed out of ordinary course. The barometer remained on both occasions unaffected up to the last moment, but as soon as the storm arrived it rose about two-tenths of an inch, and fell again as it passed over, thus showing that the propelling power was a pressure from behind, produced by the weight of the falling rain, or some other cause, and not vacuum in front as in ordinary storms. It was noticed that the thunder, caused by those flashes of lightning which struck the vessels, did not follow the flash instantaneously, but after a very perceptible interval of time, showing that from some cause the lightning travelled the last four or five hundred feet in silence. Another circumstance of a technical character, still more unexpected, was that the electrical instruments connected with the cable were not in any way affected during the storm, although they were of the most sensitive construction, and were arranged in a manner well suited to show any effects if they had existed. The vessel and rigging were of iron, and the cable was coiled in iron tanks rivetted to the sides of the vessel, yet even when the discharges were sufficient to burn pieces of canvas on the rigging, none of the electricity appeared inclined to enter the cable, but the whole escaped silently to the sea, without causing even a quiver of the galvanic needle; thus recalling to recollection Faraday's celebrated observation, that the whole quantity of electricity in a flash of lightning is not greater than that caused by the decomposition of a single drop of water.

Mr. Clapp said: He would be glad to hear whether any gentleman would state from experience whether sparks given off from a disc violently rotated, would have the appearance of a ball of fire.

Mr. G. J. Symons said: he had been to Banbury himself to look after the effects of this fire ball. There was no doubt it was a whirlwind of considerable intensity, traversing about 2 miles of country: but no person seemed to have had sufficient coolness or nerve to be able to give any account of the first mile of its course. After developing an amount of mechanical force he had seldom seen equalled in this country, and after uprooting a great many trees, the whirlwind started down a hill, and there it was seen by several men whom he had examined, carefully

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avoiding putting anything like leading questions, and he certainly could not say that their evidence came up to the account which was given by Mr. Cartwright in his letter. The men spoke of the ball of fire, because they all thought of the whirlwind as a mass of smoke, whereas it could only have been vapour. He thought the description of the appearance of sparks was probably correct. Only one man spoke of the sparks, whereas two men said the lower part of the column was a pinky sort of white: and the rapidity with which it revolved might delay a certain amount of electricity. Another thing which might partly explain the luminosity which these men saw was that the whole of the course over which the wind travelled was filled with small branches of trees, and a certain amount of friction might develop sparks, but that there was anything analagous to ball lightning that he denied, because ball lightning ordinarily occurred where there was little or no wind, and there was no analogy either between the description of the phenomena or the effects.

Mr. von Fischer Treuenfeld said Mr. Latimer Clark's description of a heavy thunderstorm in the Persian Gulf agreed with a phenomenon which was very often observed during thunderstorms. In the tropics, a heavily-charged cloud does not generally discharge its electricity in a single ray as it does in countries of moderate climate; on the contrary, it frequently takes place from a central point in many radial directions at the same time, in the way Mr. Clark had described it.

Mr. W. H. Preece, in replying upon the discussion, said he was happy to find that with one exception the speakers had been singularly unanimous in supporting the views he had expressed. He was pleased to find that his observations respecting induced currents were supported by the experience of Professor Abel with regard to premature discharges in mines and torpedoes. It so far confirmed the opinion he had previously expressed, that it was dangerous to use electricity of high potential in firing blasting charges or in gunpowder explosions in any form. He was satisfied from what Professor Abel and Captain Galton had mentioned that the clear and explicit instructions of Sir W. Snow Harris had been scarcely appreciated by the War Department, and if it were referred to a committee of this Society to determine a proper form of construction, a great deal of expense might be saved. With respect to the action of the points of a conductor, he had endeavoured to show in a diagram that they had the effect of rendering the electrification in the neighbourhood of a building s

protected, zero, and prevented the discharge falling within the area of a building so protected. The peculiar action which air—a thin layer of air encased in these lightning protectors—was experimented upon and explained by Faraday in that masterly manner which distinguished all his researches. He showed that when a charge passed through the air, or in the form of lightning, or between the coats of a Leyden jar, it simply converted the line of discharge into a conductor: it was precisely the same as if a wire connected the two points. Hence he (Mr. Preece) considered no lightning conductor could act sufficiently unless it brought earth within its reach, in order that the lightning might at once be neutralised by passing to earth. Sir William Thomson had given them some valuable information upon atmospheric electricity, and they would all go away with clearer notions of what atmospheric electricity is. There was yet a great deal to be investigated and explained as to the peculiar effects of atmospheric electricity. They had heard of the phenomena of cracks and sparks and fire-balls, and it would seem that there was some ground for them. They had also during thunderstorms the curious effects of fomentation of liquors; beer was turned sour; and in Foster's Life of Dickens there was related a singular instance of the effects of an approaching thunderstorm upon a poor idiot girl, who was seen by Dickens in an asylum at Geneva. Atmospheric electricity was at present an almost untrodden field. Some distinguished philosophers had taken it up as a pastime, but until Sir W. Thomson took it up there had been no regular or extended system of observation even hinted at. This was a subject in which a Society like this might be able to render good service by the members establishing themselves into a body of observers, and returning to a committee of the Society, or to the President, observations upon the condition of the electrification of the atmosphere over the whole world, and he was quite sure no one would appreciate those observations more than Sir William Thomson himself. He thanked the meeting for the attention with which his remarks had been received, and hoped the suggestions he had made would meet with some support.

The President rose to move a vote of thanks to Mr. Preece for his valuable paper. The paper dealt with two subjects—one a purely theoretical, and the other a practical, telegraph subject. With regard to the first—the distribution of atmospheric electricity, they had heard a very able discussion, and he thought they had all learned a great

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deal respecting that most difficult question. Practical observation on lines in countries where atmospheric electricity abounds, indicate that the distribution of atmospheric electricity is perhaps more local than most electricians suppose. For instance, if they erected a line with posts, each of them carrying a lightning discharger, even that might be no sufficient protection, seeing that between pole and pole there might be an accession of electricity in the atmosphere and discharge into the wire. The only absolute protection to a land line would be probably to make all the posts conductors, either iron posts or wooden posts with lightning conductors, and make them carry at the top a wire connected with earth all the way; but that would be expensive, and would involve many practical difficulties; therefore the next best thing was to protect the station itself. He thought it was not sufficient to protect the coil of the instrument itself, but the station should also be protected, and that was the case on all continental lines he had been connected with, where lightning abounds. The form of lightning discharger was perhaps a question open to controversy, but from all he had seen of lightning discharges those with a great many points seemed to him to be the safest guard against accidents to the instruments. One pair of points in a vacuum was a very good protector, but it could not be relied upon permanently, inasmuch as a single discharge would destroy the points, and the discharger under these circumstances was worse than useless. The plate protector was devised by his father many years ago. Although it seemed an arrangement of two plates opposite each other, it was really an arrangement of many points opposed to each other, at very short distances apart, inasmuch as the surfaces were planed in opposite directions at right angles with each other, forming a series of thousands of points, and if by the discharge some of the points were burned away there were always plenty remaining to do the work. It was necessary that care should be taken to clean these surfaces very frequently, and there was no reason why this should not be done as part of the duty of the office. The vacuum and many pointed discharges seemed to him to be the best protectors. He now begged to call upon the meeting to pass a vote of thanks to Mr. Preece for his very valuable paper.

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The President announced that this being the Annual Meeting of the Society, the ballot would take place for President, Vice-Presiden

and Council for the ensuing year, in accordance with the list which had been issued to the Members.

Mr. Louis Loeffler and Mr. E. Graves were appointed Scrutineers of the Ballot.

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The President read the following Report from the Council:—

Gentlemen,

The time has now arrived when, in accordance with the Statutes, the President and Council of your Society resign their offices, and furnish you at the same time with an account of their stewardship.

The present Council was elected on the 30th June, 1871, when the Society consisted of less than 60 Members; it will, therefore, on the 31st December, the time when the succeeding President and Council will assume office, have acted during eighteen months. During the first seven months of their term of office the Council was occupied with the preliminary work of collecting materials for our first meetings; of gaining the co-operation and support of additional members, both at home and abroad, and of concluding arrangements for securing a place for our meetings.

The First General Ordinary Meeting of this Society was held within these commodious rooms, which, you are aware, were generously placed at our disposal by the Parent Society of Engineers, on the 28th February of the current year. I ventured on that occasion to prognosticate the success of our efforts if we should gain for our enterprize a large and international basis; if we should advance upon the same in the direction of "true scientific and practical progress," and if our transactions should comprise not only the subject matter of the more elaborate papers brought before us but all matter of scientific and technical interest, relative to Telegraphy, that could be gathered by way of original communications, or by way of Abstracts and Extracts from the scientific transactions or publications of this and other countries.

The large basis thus proposed by me, with the concurrence of the Council, having been approved by the body of the Society, became henceforth our guiding principle, and it behoves me now to show to what extent we have succeeded in carrying this principle into practical effect.

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As regards the quality of the papers read before the Society during the nine months of its effectual existence, we have unquestionably every reason to be satisfied. The papers are eight in number, and embrace a great variety of subjects; they were, for the most part, presented by gentlemen who, in their capacity of departmental chiefs, were in a position to give us authentic information, and the discussions which followed were, generally speaking, well sustained.

These papers and discussions are fully reported in the two first numbers of our Journal which are in your hands, and I shall therefore here confine my notice of them to an enumeration of the subjects and of their authors, arranged in chronological order:—

March 13—On "Automatic Telegraphs," by
Mr. R. S. Culley,
M. (of Council) S.T.E.

March 27—"A Sketch of the Progress of Sea Telegraphy," by
Capt. Colomb, R.N.,
M. (of Council) S.T.E.

April 10—"On the Application of the Calculating Machine of M. Thomas de Colmar to Electrical Computation," by
Mr. Thos. T. P. Bruce Warren,
M. S. T. E.

April 26—"On Army Telegraphs," by
Capt. Malcolm, R.E.,
M. (of Council) S.T.E.

May 8—"On a Modified Form of Wheatstone's Bridge," by
Professor Foster, F.R.S.,
M. (of Council) S.T.E.

May 8—"On the Electrical Ignition of Explosives," by
Lieut.-Colonel Stotherd, R.E.,
M. (of Council) S.T.E

Nov. 13—"The Army Telegraphs and the Autumn Manœuvres," by
Major Webber, R.E.,
M. (of Council) S.T.E.

No. 27—"On Lightning and Lightning Protectors," by
Mr. W. H. Preece, C.E.,
M.S.T.E.

The last-named paper being, however, not yet published, and forming the subject for discussion this evening.

The two published numbers of our Journal contain also the following Original Communications, which were not presented in the form of papers to be read and discussed, but as interesting information, suitable for publication.

Under this head we have the following:—

"On Earth Currents and the Aurora Borealis of the 4th February, 1871," by
Mr. G. E. Preece,
Secretary. S.T.E.

"On ditto," by the Astronomer Royal.

"On the International Telegraph Convention of Rome," by
Mr. W. Andrews,
M.S.T.E.

"On combining several so-called Condensers to obtain any desired Electro-Static Capacity," by
Mr. Robert Sabine,
Treasurer, S.T.E.

besides descriptive notices of apparatus, exhibited at the two Conversaziones held during the season, by Mr. G. E. Preece, Secretary S.T.E., and some minor communications. Another original communication of a special kind is the lecture on "Telegraphy and its rise and progress in England," delivered by desire of H.M. Commissioners at the Albert Hall (but in connection with our Society) by Mr. W. H. Preece, M.S.T.E.

In addition to these original contributions, the two published numbers of our Journal contain 29 Extracts and Abstracts from English

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and Foreign publications, prepared and elaborated by the members of your Publishing Committee. The useful action of this Committee although as yet imperfectly developed, can hardly be over estimated. It is composed at present of the following gentlemen:—

Mr. C. Wm. Siemens, President.

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| Dr. Atkinson. | Mr. H. R. Kempe. |
| Major Bolton. | Major Malcolm. |
| Mr. G. von Chauvin. | Mr. George Preece. |
| Mr. Latimer Clark. | Mr. Robert Sabine. |
| Captain Colomb. | Mr. Carl Siemens. |
| Mr. R. S. Culley. | Colonel Stotherd. |
| Professor Foster. | Major Webber. |

Mr. H. S. Wilson.

It is the purpose of this Committee to make our Journal a complete repertory of the progress of Telegraphy and of Electrical Science in connection with Telegraphy, and it can scarcely be doubted that such a publication will command a general and an enduring interest among a large body of men of this and other countries. It is equally certain, however, that the accomplishment of such a task, though highly advantageous to the interests of our Society, must involve an expenditure exceeding the annual subscriptions. A separate Publishing Fund had therefore to be established, which I am happy to state has already produced over £200 by way of donations and subscriptions, and which will, I trust, receive still greater support when our objects and necessities, as well as the results produced, are more generally known, a list of the Subscriptions is appended.

The numerical growth of our Society has been highly satisfactory On the 28th February of the present year, we counted 110 members of all classes, and on this day our numbers stand as follows:—

20 Foreign Members.
153 Ordinary do.
178 Associates.
2 Students,

making a total of 353 members of all classes, and representing an increase of 243 during the nine months of our effectual existence.

But let it not be supposed that we intend to put forward these flattering statements in proof of a faultless discharge of our several functions. On the contrary, we desire rather to prove the vitality of our Society notwithstanding our, as yet, imperfect organization, and many shortcomings or errors of judgment which may have been

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noticed in our proceedings. The two published numbers of our Journal by no means realize the high aim which we have set before us, but it was no easy task to arrange, abridge, and classify the incongruous mass of information within our reach; experience will teach us how we may improve in this respect. One of the principal features of our publication should be original communications, but some time must necessarily elapse before our members, particularly those residing in the country or abroad, will fully appreciate the advantage to the Society and to themselves of a special vehicle for conveying their researches speedily to their *confrères* in all parts of the world, and of having them placed on record for easy reference. On the other hand, it is the duty of the Publishing Committee to reject all trivial, unsound, or simply controversional communications.

Although the Chiefs of the Foreign telegraphic systems have for the most part joined our Society as Foreign Members, we have hardly had time and opportunity as yet to cultivate our Foreign relations, or to rise to the dignity of an International Institution. It will be necessary for this purpose to appoint in each Country or principal City, a corresponding Foreign Member, whose duty it will be to make our Society known in the proper quarters, to invite suitable persons to join the Society, to invite original communications, and to collect our annual subscriptions. With these and other minor improvements in our organization in view, and relying upon the hearty co-operation of the Members of all classes, I shall leave this chair in the firm hope that the Society of Telegraph Engineers will soon take a high position among scientific bodies.

During the year, the following presents have been made to the Society, which have been duly acknowledged.

Regarding myself, I will only add that I shall ever feel and evince the warmest interest in the welfare of the Society.

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## PRESENTS.

M. D'Amico—

Statistical Information, for 1871, of the Italian Telegraphs.

Colonel Meydam—

Statistical Information, for 1871, of the Imperial German Telegraphs.

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MR. A. BRASHER—
The Vienna Convention, 1868.
The Roman Convention, 1872.

MR. L. SCHWENDLER—
Instructions for Testing Telegraph Lines.
On differential Galvanometers.

SIR G. B. AIRY, K.C.B., Astronomer Royal—
Tracings of Photo-Records of the various Magnetometers at the Royal Observatory during the "Aurora" of February 4th, 1872.

MR. NIELSEN—
Specimen of Gutta Percha Wire, from Norway, damaged by "Xylophaga."

MR. C. V. WALKER, F.R.S.—
The effects of a Lightning Flash on the steeple of Brixton Church, and observations on Lightning Conductors generally. 1842.
Memoir on the difference between Leyden Discharges and Lightning Flashes. 1842.
Observations on a Paper by C. V. Walker, Esq., "On the action of Lightning Conductors," by W. Snow Harris, Esq. 1842.
Proceedings of the Electrical Society, complete in 8 Nos.
Electrical Magazine, Vol. 1.
Electrical Magazine, Vol. 2, 6 Nos., all published.
De la Rive's Electricity, Vols. 2 and 3.
Action of Lightning Conductors.
Magnetic Storms and Earth Currents.
Magnetic Calms and Earth Currents.
Transactions of the London Electrical Society (complete).

SOCIETY OF ENGINEERS—
Transactions of the Society of Engineers for 1870.

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# STATEMENT OF RECEIPTS

*From September*, 1870, *to*

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| To Subscriptions ... ... ... | 422 | 15 | 0 | | | |
| „ Arrears ... ... ... ... | 110 | 14 | 6 | | | |
| | | | | 312 | 0 | 6 |
| „ Publishing Fund Subscriptions and Donations ... ... ... | 216 | 4 | 0 | | | |
| „ Arrears ... ... ... ... | 44 | 4 | 6 | | | |
| | | | | 171 | 19 | 6 |
| „ Sale of Journals, &c. ... ... ... ... | | | | 20 | 1 | 3 |
| „ „ Pamphlets ... ... ... ... ... | | | | 13 | 0 | 6 |
| | | | | £517 | 1 | 9 |

ASSETS OF SOCIETY, ON 31ST DECEMBER, 1872.

| | | | |
|---|---|---|---|
| Cash Balances ... ... ... ... | 41 | 1 | 7 |
| Arrears Subscriptions ... ... ... | 110 | 14 | 6 |
| „ Publishing Fund ... ... | 44 | 4 | 6 |
| Stock of Nos. 1 & 2 Journals ... | 124 | 2 | 6 |
| Total Credit ... ... | £320 | 3 | 1 |

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# AND EXPENDITURE

31*st December*, 1872

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| By Expenditure— | | | | | | |
| Preliminary Expenses ... ... | 48 | 5 | 9 | | | |
| Salaries ... ... ... ... | 83 | 13 | 4 | | | |
| Shorthand Writer (Reports) ... | 17 | 6 | 6 | | | |
| Clerks, Messengers, Tea and Coffee at Meeting ... ... | 15 | 0 | 10 | | | |
| Postage, &c. ... ... ... | 31 | 14 | 11 | | | |
| Exhibition ... ... ... | 8 | 12 | 4 | | | |
| Stationery... ... ... ... | 63 | 13 | 3 | | | |
| Publication ... ... ... | 207 | 13 | 3 | | | |
| | | | | 476 | 0 | 2 |
| Balance Cash ... ... ... | | | | 41 | 1 | 7 |
| | | | | £517 | 1 | 9 |

Examined and compared the above Account with the Vouchers and the Cash Book, and find this Account to be correct, leaving a Balance in the hands of the Treasurer of Forty-one Pounds One Shilling and Seven Pence.

(Signed) J. WAGSTAFF BLUNDELL,
F. C. DANVERS, } *Auditors.*

FRANK BOLTON, *Treasurer pro tem.*
GEO. E. PREECE, *Secretary.*

*December* 31*st*, 1872.

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THE PRESIDENT then announced the following as the result of the ballot:—

## COUNCIL.

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### PAST-PRESIDENT.

CHARLES WILLIAM SIEMENS, M. INST. C.E., F.R.S., D.C.L.

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MAJOR WEBBER, R.E.
EDWARD WILDMAN WHITEHOUSE
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JOHN BORDEAUX. | PROFESSOR BOTTOMLEY.
H. G. ERICHSEN.

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### AUDITORS.

J. WAGSTAFF BLUNDELL.
FREDERICK C. DANVERS (India Office).

### TREASURER.

MAJOR WEBBER, R.E.

### HON. SECRETARY.

MAJOR FRANK BOLTON.

### SECRETARY.

G. E. PREECE.

Mr. H. WEAVER proposed a cordial vote of thanks to the President for the very able and efficient manner in which he had performed his duties during his term of office.

The motion having been duly seconded was passed by acclamation.

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*The following Candidates were balloted for and duly elected:—*

As Foreign Members:—

Carl Frischen, Berlin.
C. H. Haskins, Milwaukee, U.S.
W. P. Sargent, Philadelphia, U.S.
C. H. Summers, Chicago, U.S.

As Members:—

Dr. John Hall Gladstone, F.R.S., 17, Pembridge Square, W.
F. R. James, Government Telegraph Department, Melbourne.
C. Lemon, Government Telegraph Department, Melbourne.
G. K. Winter, F.R.A.S., Arconum, Madras.

As Associates:—

Thomas Andrews, Brest, France.
George Arnold, Post Office Telegraphs, Telegraph Street.
John Arnold, ,, ,,
S. M. Banker, ,, ,,
James A. Betts, ,, Oxford.
Henrik Bohr, Amoy, China.
John Brown, Duxbury, U.S.
G. H. Dixon, Post Office Telegraphs, Telegraph Street.
Charles T. Fleetwood, ,, ,,
J. T. Hill, ,, ,,
Thomas Hill, ,, ,,
Frederick Irminger, Hong-Kong.
Robert Bristow Lee, Manchester.
J. M. Maclachan, Post Office Telegraphs, Telegraph Street.
Frederick Moll, 16, Telegraph Street.
Charles A. Morgan, Post Office Telegraphs, Telegraph Street.
John Munro, C.E., Hooper's Telegraph Works, Millwall.
George Stevenson, Eastern Telegraph Company, Alexandria.
Frederick G. Teale, India Government Telegraphs.
Edwin T. Truman, 23, Old BurlingtonStreet.

The Meeting then adjourned.

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# ORIGINAL COMMUNICATIONS.

## ON A NEW FORM OF JOULE'S TANGENT GALVANOMETER.

By Sir William Thomson, F.R.S., LL.D.

Nearly thirty years ago Joule showed how to make a good tangent galvanometer.* Yet, up to the present time, the tangent galvanometer described in the text-books and made by the chief instrument makers has for needle a heavy steel bar two or three inches long, supported by an agate capsule on a steel point; and is nowhere properly placed except in a historical museum. It is certainly useless in the laboratory or the electrician's testing room.

Joule's improvement, subsequent to the meeting of the British Association at Cork in 1843, consists in substituting for the point and agate capsule, suspension by a single silk fibre; for the great steel bar, a very light needle about a quarter inch long, or, at the most, half an inch; or two or more such needles cemented parallel to one another on an exceedingly light cradle: and for the bar itself as pointer an exceedingly light glass rod or tube cemented to the needle or cradle, pointing degrees of deflection on a graduated horizontal circle. The cradle ought to be the very lightest that can bear the needles, and the glass pointer the lightest that can bear its own weight without drooping to an inconvenient extent. By fulfilling these conditions, and particularly by making for the pointer a glass tube about six inches long, and so light that its ends droop about a quarter inch each below the level of its middle, and by making the floor and glass roof of the case protecting it from currents of air as close together as they can conveniently be to allow the pointer freedom to turn without touching them, Joule long ago produced an instrument with the distinguishing merit of my more recent "dead-beat mirror." When the current through the coil is suddenly made, or reversed or broken, the indicator moves direct to its fresh position without shooting past it, and reaches it sensibly in,

* Not before the Meeting of the British Association at Cork, in 1843, certainly; not long after, probably. *See*, in the Association's Report of that year, abstract of his Paper "On a Galvanometer."

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at the most, two or three seconds of time. I do not think it an exaggeration to say that, with an instrument having these qualities, as many accurate observations can be made in ten minutes as can be made in an hour with the ordinary instruments which oscillate most tediously before settling sufficiently to show the position of equilibrium. With an instrument constructed for the University of Glasgow, about twenty-five years ago, (by Mr. Dancer of Manchester, under the direction of Joule himself,) in which the circle is six inches diameter, and is divided into degrees and halves of a degree, I find that by using reversals, and taking the means of the four readings of the two ends of the needle in the two positions, I can readily obtain results, trustworthy to within 2′ or 3′, of the true value of the single deflection.

The new form of Joule's instrument now before the Society, has several modifications, which I have introduced chiefly to render it more convenient for the practical electrician, but partly, also, to save time in measuring the resistances and intensities of galvanic elements in the scientific laboratory. These modifications are:—

No. 1.—Instead of a single fixed coil, two coils, supported on geometrical slides, so as to be moveable to different distances from the needle, in the direction perpendicular to the magnetic meridian on the two sides.

No. 2.—Simple appliance to produce change from connexion of the two coils in series, to connexion in double arc, when one of them is brought nearer to the needle than a certain position on its slide.

No. 3.—Two long coils, with a great number of convolutions, of fine wire, so as to give a resistance immensely greater than that of any single element, or even battery, to the measurement of which the instrument is to be frequently applied.

No. 4.—Copper wire of high conductivity, a condition which, so far as I am aware, has never been attended to in any tangent galvanometer hitherto made, except a few by White, including the instrument now before the Society.

No. 5.—Division of the scale, to show equal differences of tangents of the angles, from zero, instead of equal angular differences.

No. 6.—Simplified details of suspension and adjustment, including an exceedingly convenient mode devised by Mr. White for lifting the cradle, and supporting it firmly, without breaking the fibre, so as to render the instrument readily portable.

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The object of No. 1 is to render the instrument readily applicable to test the resistances and intensities of batteries of from 2 to 100 cells. The object of No. 2 is to give sufficient sensibility for satisfactorily measuring the intensity of a single Daniell's cell. The object of No. 3 is to give the simplicity of the method by electrometer, to testing the resistance and intensity of a battery by galvanometer. The object of No. 4 is obvious, and it is worthy to be noticed by the Society of Telegraph Engineers, that it has hitherto been so lamentably neglected. The object of No. 5 is to avoid the necessity of using a table of natural tangents, and to save time when numerous tests have to be made.

The instrument shewn this evening to the Society is merely a rough first trial towards the construction of a galvanometer fulfilling the conditions I have described. I hope at a future meeting to be able to show an instrument with the constructive details improved in many important particulars. Such an instrument, ordered by Mr. Saunders for the Eastern Telegraph Company, is now being made by Mr. White, and a sufficient description, if not the instrument itself, will I hope soon be placed before the Society. Among other improvements it will have a plain mirror of silvered glass, instead of white paper, for the floor of the case, in the immediate neighbourhood of the graduated arc. This, according to a well-known old German plan, will greatly promote accuracy in reading the deflections, by facilitating the avoidance of parallactic error.

## ON THE MEASUREMENT OF ELECTROSTATIC CAPACITY.

By Sir William Thomson, F.R.S., LL.D.

The ordinary methods of measuring electrostatic capacity in which a galvanometer is used to measure the electro-magnetic impulse, on the same dynamical principle as that adopted by Robins in his ballistic pendulum, are liable to very serious objections:—

No. 1.—It is difficult to secure that the whole duration of the impulse shall be a sufficiently small fraction of the needle's period.

No. 2.—The resistance of the air or of other fluid employed to damp the vibrations of the needle, directly affects the observed throws, to amounts which cannot easily, if at all, be determined with accuracy.

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No. 3.—On account of (1) and (2) it is necessary for accuracy that the period be long, and the resistance against the motions of the needle so small that the diminution of amptitude in successive swings shall be small. An instrument fulfilling these conditions is exceedingly inconvenient for practical use, because it is difficult, or at least tedious, to get the needle brought to rest, as it must be before taking a discharge upon it. Such an instrument is indeed rather suitable for the physical laboratory than for a cable-station, a ship, or a telegraph engineer's testing room.

No. 4.—The intensity of the electro-magnetic action during the instant of the discharge is liable to alter the magnetization of the galvanometer needle (which is sometimes a fatal objection to the method, whether a single discharge, or contrary discharges through a differential galvanometer be used).

The difficulty No. 2 has been met in practice hitherto, most commonly, I believe, by using a differential galvanometer to reduce the observed throw to zero, or to a small proportion of that due singly to one or other of the two quantities compared. But the use of a differential galvanometer aggravates curiously, and sometimes inconveniently, the difficulty No. 1. Unless the period of the needle is much longer than it is in any of the galvanometers ordinarily used, the contrary discharges through the two coils must be very accurately simultaneous, to avoid giving undue influence to the greater of the two discharges, whichever of the two be the first made.

Whether the differential galvanometer be used, or the method by single discharges, the period of the needle must be many times greater than any that would be convenient for the practical electrician, if either method is to be applied to measure the capacity of lengths of submarine cables, exceeding one or two hundred miles.

De Sauty's beautiful method, (Clark and Sabine, Electrical tables and Formulæ. Edition 1871, page 62,) though nearly free from all the difficulties described above, when applied to short lenghts of submarine cable, or to condensers or other ordinary laboratory apparatus, is not applicable to great lengths of submarine cable on account of the manner in which the currents concerned in it are influenced by the inductive retardation.

Two methods, one or other of which I have generally perferred, even for laboratory work, are quite free from all the difficulties referred to above, and are equally applicable to several thousand miles

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of submarine cable, and to leyden jars, or ordinary electrostatic apparatus of even smaller capacity. The first of these methods was described at the meeting of the British Association in Glasgow, in 1855, and a short statement of a method virtually agreeing with the second was communicated to the British Association Committee on electrical measurements, four or five years ago, but no full practical description of either has been hitherto published.

My first method consists of a purely electrostatic arrangement analogous to the method for currents commonly known as Wheatstone's bridge. Four condensers are arranged in two series of two each. The two first plates ($a$, $A$) of the two series are connected together. So are the two last plates ($a'$, $A'$). An electrometer* or

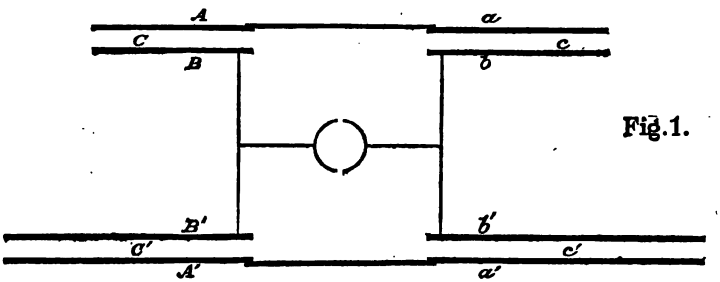


Fig. 1.

galvanometer is employed to test differences of potential between the intermediate connected plates ($b$, $b'$) of one series, and the connected plates ($B$, $B'$) of the other series, after a difference of potentials has been suddenly established between the first plates and the last plates of the series. If the difference of potentials is found zero, we conclude that

$$c : c' :: C : C'$$

where $c$ and $c'$ denote the capacities of the two condensers in one series, and $C$ and $C'$ those of the other two in the same order, in the other series. When a galvanometer is employed to test the difference of potentials, its circuit must not be made until time enough has been allowed for the establishment of electrostratic equilibrium among the condensers. The time required for this is a very small fraction of a second, in ordinary laboratory work, and in applications of the method to short lengths of submarine cable, or to the testing of condensers of hundreds of microfarads, provided there is no resistance of more than a few ohms in any of the connections concerned.

* It was for this application that sixteen years ago I first though of the "divided ring electrometer," of which the modern quadrant electrometer is a species.

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On the other hand, in testing considerable lengths of submarine cable (or in experiments in which, as with Varley's "artificial line," condensers of great capacity are connected through great resistances) two, three, or more seconds may be necessary before the zero test can be taken. To produce the zero, one or more of the four capacities $c$, $c'$, $C$, $C'$, must be altered by a proper method of adjustment, When an electrometer is used, and when the insulation is very good, the zero may be obtained by this adjustment, without a fresh electric charge; but, after having obtained the zero, it will, of course, be right to discharge the apparatus and re-test with fresh charge. On the other hand, when a galvanometer is used, the condensers must be thoroughly discharged, then re-charged and left for time enough to secure electric equilibrium before testing again the desired equality of potentials by the (quasi-bridge) discharge through the galvanometer: and so after repeated trials the adjustment of capacities giving zero effect on the galvanometer, and therefore securing the proportion $c : c' :: C : C'$, is found. The details of this method admit of much variation, according to the nature and character of the investigation to which it is applied, and of the available instruments. One way of carrying it out, adapted to very small capacities, is fully described in a paper entitled "Measurement of Specific Inductive Capacity of Dielectrics," by John Gibson, M.A., and Thomas Barclay, M.A.—(*Transactions of Royal Society for Feb.*, 1871).

My second method is still analogous to the Wheatstone bridge, but differs from the first in this, that one only of the two connected series consists of condensers, and that the other is a line of current through resistance. The two condensers ($c$, $c'$) to be compared are put in series, that is to say, one plate of the condenser $c$, which will be called its second plate, is put in connexion with one plate of condenser $c'$, which will be called its first plate. The first plate of condenser $c$ will

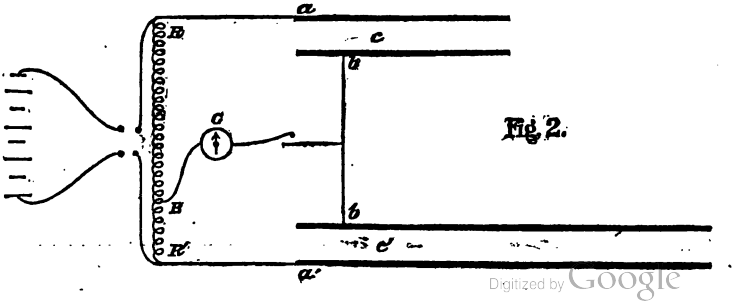


Fig. 2.

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be called $a$, the connected second plate of $c$ and first plate of $c'$ will be called $b$, and the second plate of $c'$ will be called $a'$. Join $a$ and $a'$ in metallic connection through a wire $aBa'$ of not less than several thousand ohms resistance, and let $B$, a point in this line of conduction be put in connection with one terminal of an electrometer or galvanometer, the other terminal of which is to be occasionally connected with $b$, by a make and break key, $M$. To commence, make and break contact at $M$ several times, not too rapidly, and observe the effect on the indicator whether of electrometer or of galvanometer. Then with contact at $K$ broken, establish a difference of potentials between $a$ and $a'$ by means of a battery, and after time has been allowed for electric equilibrium between $c$ and $c'$, make contact at $M$, and keep it made for a sufficient time. They break contact at $M$ and reverse the battery electrodes between $a$ and $a'$. Then after sufficient time for re-establishment of electric equilibrium between $c$ and $c'$, make contact at $M$. The ratio of the resistances $R$, $R'$, between $a$ and $B$, and between $B$ and $a'$ must be adjusted by varying one or both of them until the effect of making contact at $M$ is the same with successive reverse applications of the battery to $a$ and $a'$ (This effect will be zero, generally in laboratory and factory tests, but, because of earth-currents, not exactly so in a submerged cable). When the adjustment has been satisfactory made, we conclude that

$$R' : R :: c : c'.$$

This method is applicable, notwithstanding earth currents in moderation, to measure the resistance of a submerged cable of two or three thonsand miles length, with only a single microfarad as standard for capacity, and a battery of not more than 100 cells to charge it.

$$C : C' :: c : c',$$

Let $C$ and $C'$ denote the conducting powers, that is to say, the reciprocals of the resistances, of the two parts $a\ B$, $B\ a'$, of the conducting arc $aBa'$. The relation of proportions for equilibrium thus stated shows the analogy with my first method.

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## TESTS OF BATTERY.

By Sir William Thomson, F.R.S., LL.D.

To measure the intensity and resistance of a cell or series of cells, use a galvanometer with a very long coil, and add resistance to it to make up a total resistance many times greater than the greatest internal battery resistance to be measured. A tangent galvanometer of the new form made for this purpose, with arc divided according to tangents, so that the readings on its scale are simply proportional to the currents, is very convenient. The resistance of its coils in series is about 4,000 ohms, and by varying the distance of the coils from the needle it may be applied without any other change of adjustment, to any battery of from one to fifty cells. A mirror galvanometer with strong controlling magnet or magnets to give very quick action to the needle is also very convenient. Its sensitiveness will still be sufficient to require the addition of from one hundred to four hundred thousand ohms resistance to its circuit. The proper degree of sensitiveness ought to be produced by controlling magnets and by adding resistance; without in any case applying a shunt to its coil. The galvanometer should be kept in one place, and convenient leading wires used as electrodes from whatever cell or battery is tested. The suspending fibre, whether the mirror or the tangent galvanometer be used, must be so fine as not sensibly to disturb the zero. To make an observation, provide a suitable resistance coil, which for brevity will be called the shunt. This coil should have thick flexible electrodes convenient for direct application to the two terminals of the cell or battery to be tested. Its resistance may be anything from about one half, to two or three times the resistance of the battery to be tested. Its length ought never to be less than two metres for testing a single cell; or twice as many metres as there are cells in the series to be tested. If its resistance is to be anything lower than one ohm it may be conveniently made by a strand of two, three, or more wires twisted together. These wires may be silk-covered or cotton-covered, copper or german silver. Or bare wire of either metal may be used: and if so the strand must be taped, or otherwise sufficiently insulated, to securely separate the different turns in the coil from metallic contact with one another. If too short a length is used the heating action of the cell is too great; and therefore although two metres may be allowed as a minimum, a considerably greater length is preferable.

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When the length is only two metres per cell tested, the current ought not to be allowed to flow through the shunt for more than two or three seconds at a time, or it may become too much heated.*

To make an observation:—First observe the deflection (D) produced by the battery through the simple circuit of the galvanometer, and added resistance if any. Then apply the shunt direct to the terminals of the battery, making sure of good contacts; and observe the reduced deflection D′. Let S be the resistance of the shunt, and B the resistance of the battery, we have—

$$B = S\frac{D - D'}{D'}\dagger$$

If D—D′ is too small a number of divisions to give a good result, a shunt of less resistance must be used. If, on the other hand, D′ is too small, a shunt of greater resistance must be used. When a battery consisting of any number ($n$) of cells in series is thus tested, $\frac{B}{n}$ is the mean internal resistance per cell. When a single cell is tested, B is simply the resistance of that cell. The intensity of the cell is inferred from the single deflection D, by noting what a single cell of good quality would give when tested in the same way. Thus, if V denote the deflection which would be produced by the electromotive force of one volt, a single good Daniell's cell would give a deflection equal to $1{\cdot}07 \times V$. By applying once for all a good Daniell's cell and dividing the observed deflection by 1·07, we have a fair approximation to the value of V for the particular adjustment of galvanometer used. Of course, if the adjustment is changed, the value of V must be re-determined. Supposing, then, V to be known for the adjustment actually used at any time, we have—

$$E = \frac{D}{V},$$

* If the current is kept flowing through a copper wire, with an electromotive force amounting to that of one good Daniell's cell per n metres, the temperature of the wire would rise at the rate of $\frac{15}{n^2}$ degrees centigrade per second, were no heat allowed to leave it.

† The rigorous formula is as follows:—

$$B = S\,\frac{D - D'\,\frac{G}{G+S}}{D' - D\,\frac{S}{G}},$$

where G denotes the resistance of the galvanometer circuit—that is to say, the resistance of the galvanometer coil, together with the added resistance if there is any. When G is very great in comparison with S, $\frac{G}{G+S}$ is very nearly unity, so that the numerator becomes D—D′, nearly enough for practical purposes; and $\frac{S}{G}$ being a very small fraction the denominator becomes nearly enough D′: thus we have the simple approximate formula in the text.

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where E denotes the intensity of the electromotive force, in volts, of the cell or battery tested in the process described above. If $\frac{E}{R}$ is found to be much less than 1·07 the battery is defective in intensity. Let E be the electromotive force of the battery in volts: B its internal resistance, and R the internal resistance of the electro-magnetic coils through which its circuit is completed when at work, each reckoned in ohms. The quantity of electricity circulating per second will be

$$\frac{E}{B + R}$$

reckoned in terms of a unit equal to the quantity required to charge a condenser of one farad to a potential of one volt. The quantity of zinc dissolved in each cell amounts therefore to $\frac{1}{3000} \times \frac{E}{B + R}$ grammes per second, or $1{\cdot}2 \times \frac{E}{B + R}$ grammes per hour, and the quantity of sulphate of copper used is

$$4{\cdot}75 \times \frac{E}{B + R} \text{ grammes per hour.}$$

For example, suppose twenty of the ordinary recorder trays in good condition to be employed. The electromotive force will be about 21 volts, and the whole internal resistance about three ohms. The coils of the electro-magnet, if in series, will give a resistance of about 14 ohms. Putting then $E = 21$, $B = 3$, $R = 14$, we have

$$\frac{4{\cdot}75 \times 21}{17}$$

that is 5·9 grammes, for the consumption of sulphate of copper in each cell per hour, or 100 grammes * in seventeen hours

The efficiency of the whole battery, and of each cell of it separately, when actually at work on the recorder electro-magnet, is to be tested as follows, without in any way interrupting or disturbing the use of the instrument for signalling:—Carry electrodes from the galvanometer first to the two terminals of the electro-magnet, and observe the deflection D. Then place them successively upon the two terminals of each cell, and observe the deflections in each case, $D_1$, $D_2$, etc. It will be found that the sum of these is equal to D. At any time when the instrument is not required for signalling, the intensity and the resistance of each cell may be determined without the use of a separate shunt, by the following process, which will be found very easy and convenient in practice:—Keep the electrodes of the

* This is as nearly as may be at the rate of four ounces in 19 hours, or a pound in 76 hours. An ounce avoirdupois is 28·3 grammes. 1 lb. is 453 grammes.

whole battery on their proper places on the terminals of the electro-magnet coil, and find D as above. Then as above find $D_1$. Then without moving the galvanometer electrodes from the terminals of the first cell, break the electro-magnet circuit by the proper make and break switch. Let $D_1$ be the deflection then observed. Proceed similarly for each of the other cells, and let $D_2$ $D_2'$ $D_3$, $D_3'$, etc., be the observed deflections. Then if $B_1$ $B_2'$, etc., denote the resistance of the several cells, and $E_1$, $E_2$, etc., their intensities, we have—

$$E_1 = 1{\cdot}07 \times \frac{D_1'}{C}, \quad E_2 = 1{\cdot}07 \times \frac{D_2'}{C}, \text{ etc.}$$

$$B_1 = R\,\frac{E_1 - D_1}{D}, \quad B_2 = R\,\frac{E_2 - D_2}{D}, \text{ etc.}$$

where R denotes the resistance of the electro-magnet coil. In the recorder as now made, R will be about 16 ohms when the two coils are in series, and about 4 ohms when they are connected in double arc. Let C be the deflection given by a good Daniell's cell direct through the galvanometer. The actual efficiency of the whole battery, as working on the electro-magnet reckoned in volts, will be—

$$1{\cdot}07 \times \frac{D}{C};$$

and the efficiency of the several seperate cells in terms of the same unit, will be,

$$1{\cdot}07 \times \frac{D_1}{C}, \qquad 1{\cdot}07 \times \frac{D_2}{C}, \text{ etc.}$$

In observing the deflection for each cell, be careful to note its direction. There might be a fair degree of deflection from any one cell of a battery in series, but yet its direction might be opposite to that corresponding to positive efficiency. This would be the case, for example, if, in a battery of $n$ cells in good order as to intensity, the resistance of any one cell exceeds one $n^{th}$ part of the sum of all the resistances, internal and external, in the circuit. When this is found to be the case for any cell, either short circuit it immediately, or refresh it by putting in crystals of sulphate of copper.

The cells in actual use are to be tested in the manner just described, as frequently as is necessary to make sure of their efficiency. Until a cell has been a fortnight at work, it will, generally speaking, not show any failure in efficiency except through want of sulphate of copper.

Supposing 14,000 grammes to be the weight of water in each

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tray, the dissolution of 840 grammes of zinc will raise the specific gravity from 1·1 to 1·3. This would result from the consumption of 3400 grammes (or 120 ounces) of sulphate of copper. Keep account of the quantities of sulphate of copper put into each tray, from time to time; also occasionally, before putting in the fresh sulphate of copper, test the specific gravity by a hydrometer. Before the specific gravity of the stratum of liquid level with the zinc grating reaches 1·35, draw out some of the liquor, and pour fresh water into the space over the zinc.

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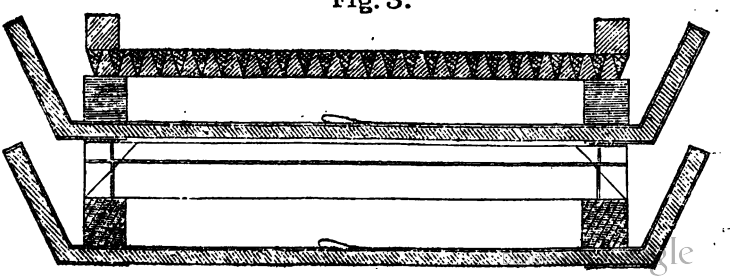
## TRAY BATTERY FOR THE SIPHON RECORDER.

By Sir William Thomson, F.R.S., LL.D.

The battery consists of square wooden trays lined with lead, and zinc gratings resting in them on wooden or stone-ware props. In the lower edge of each tray, on the outside, a groove is cut to facilitate pouring in fresh water over the zincs, during the use of the battery. A stout copper wire is soldered to the lead lip of each tray, to facilitate making connection to electrodes when required. To allow the deposit of copper to be readily removed, a narrow slip of sheet copper is soldered to the lead near the middle of the bottom of each tray, and all the rest of the lead both over the bottom and on the slant sides is carefully coated with paraffin, bees wax, or other non-conducting material, such as varnish of any convenient kind; and a piece of dutch metal paper, with its metallic side up, and with the slip of copper passing through a hole in it to its upper side, is parted flat down over the varnished bottom. The slip is then bent and sprung so as to press with its end firmly on the metallic surface.

Tray Battery.

Fig. 3.



The same object may be attained by the following alternative process, with less trouble, in case of setting up afresh old lead trays, which, from want of the precaution, have been ruffled by a deposit of copper adhering to them too firmly to be removed. The whole of the lead, bottom and slant sides, of the tray, must be thickly varnished, except a small area of a quarter of an inch diameter at the centre, which must be cleaned so as to present a fresh metallic surface, to make contact with a sheet of copper placed in the bottom of the tray, and to receive enough of deposited copper to establish a permanent metallic connexion between the lead and the sheet of copper. To make sure of an initial contact between the copper and the lead, a burred hole is made in the centre of the sheet of copper, (by a round-headed punch, the copper being placed on a piece of soft wood,) before it is put into the tray. The under surface of the copper plate must be also carefully varnished except the burr projecting downwards. In laying the sheet of copper in the bottom of the lead tray, it must be so placed that the bur presses on the clean portion of the lead. When properly placed, secure it by wax at its corners and edges so as to prevent it from shifting, and to keep it lying flat in case of any part of it showing a tendency to curl up.

Each zinc is to be protected by a square of parchment paper bent round below it, and folded neatly at the corners and fixed with sealing wax.* Care must be taken that the edge of the paper be generally $\frac{3}{4}$ inch (and in no place less than a $\frac{1}{4}$ inch) above the upper level of the bars of the zinc grating. It must be bound firmly to the zinc, by twine passing under the parchment paper, and tied over the zinc above; also by a long piece of twine several times round the square. Each lead tray should have a stout copper wire soldered to it, projecting about three inches from one corner.

To support a pile of trays take four blocks of wood each four or five inches square in horizontal dimensions and of any convenient height: and place them in positions to bear the four corners of a tray. The pile must be so placed as to give ready access to each of its sides. Put a piece of thick sheet gutta-percha, six inches square, on the top of each of the wooden squares, and then lay down the first tray upon

* Press the paper against the zinc between finger and thumb on each side of the corner and draw the bight or bend of the paper diagonally away from the corner; then fold the bight round the vertical corner of the zinc, and press it against the flat zinc surface on one side or other of the corner. Secure with sealing wax in the bight, and where one side of it is pressed against the paper on the vertical zinc surface. Then tie it round carefully with cord in the manner described in the text.

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them, seeing that it is properly levelled. Put four hard wood or stone blocks, each 1½ inch cube, in the corners of the tray, and put one of the zinc gratings resting with its four corners on these props. Put a quarter-saturated solution of sulphate of zinc (specific gravity about 1.1) into the tray, pouring in first between the lead and the parchment paper, and afterwards filling up to the level of the top of the zinc grating, by pouring some of the solution directly on the zinc over the paper. See that the top corners of the zinc, and the bottom corners of the tray to rest upon it, are all properly tinned, and clean and dry. Place a lead tray resting with its four corners on the upper projecting corners of the zinc. Place four wooden or stone props in the corners of this second tray, put a second zinc upon them, and fill with solution as before. Observe in placing the trays, to turn them with their grooved edges on the same side of the pile, and *that* the side most convenient for pouring in fresh water. Proceed thus until a pile of from six to ten trays, one over the other, is made and filled with liquid. Solder a stout copper wire for electrode to one of the corners of the top zinc. In the same way make as many piles as are required. Leave a space of about one foot breadth between each pile and its neighbour. Connect these piles in series, the top zinc of one pile to the lowest lead tray of the next one.

The crystals of sulphate of copper to be used should be broken into small pieces, the largest not more than the size of a pea, and weighed out in quantities of an ounce each. To put the battery in action drop in four ounces to each cell; one ounce separately on each side, distributing it as equally as may be, along the space between the wooden props; and immediately after doing so, short-circuit the cell, and keep it on short-circuit till required for use. Within a short time (ten minutes or a quarter of an hour) the battery will be ready to act at full power. Take care not to drop in any crystals so near the corners as to fall against the wooden or stone props.

From time to time put in more sulphate of copper; always regularly four ounces to each tray, one ounce separately along each side. as in first charging the battery: but never put put in a fresh supply of the crystals until the previous supply is nearly all used up. If at any time the battery is to be out of use for several days, short-circuit it until all the sulphate of copper is used up. The short-circuit should be broken when there is no sulphate of copper

remaining in any of the trays. From time to time draw off by a siphon from a point a little below the lowest level of the zinc, enough of the liquor to sink the surface by about a quarter of an inch; and then fill up to the proper height by pouring in fresh water by a funnel to the space above the grating bars. The specific gravity of the liquor drawn off each time should be tested by a hydrometer, and the quantity drawn off should be regulated so as keep the specific gravity of the liquor in the cell at about from 1·15 to 1·35.

## APPENDIX.

### TABLE OF CHEMICAL ATOMIC WEIGHTS.

| Substance. | Symbol. | Atomic Weight. |
|---|---|---|
| Copper ... ... | Cu ... | 63·4 |
| Zinc... ... ... | Zn ... | 65·2 |
| Sulphur ... ... | S ... | 32 |
| Oxygen ... ... | O ... | 16 |
| Hydrogen ... ... | H ... | 1 |

Crystallized sulphate of copper ($Cu\,S\,O_4 + 5\,H_2O$) contains

| | | |
|---|---|---|
| Metallic Copper ... ... | 25·4 | per cent. |
| Sulphur ... ... ... | 12·8 | „ |
| Oxygen ... ... ... | 57·7 | „ |
| Hydrogen ... ... ... | 4·0 | „ |

Crystallized sulphate of zinc ($Zn\,SO_4 + 7H_2O$) contains

| | | |
|---|---|---|
| Metallic Zinc ... ... ... | 22·7 | per cent. |
| Sulphur ... ... ... | 11·1 | „ |
| Oxygen ... ... ... | 61·3 | „ |
| Hydrogen ... ... ... | 4·9 | „ |

The following Tables, giving the densities of various solutions of sulphate of copper and sulphate of zinc up to saturation are extracted from Storer's Dictionary of Solubilities (1864).

| Per-centage of crystallized sulphate of copper in solution. | Specific gravity of solution at 18° Cent. |
|---|---|
| 5 | 1·0319 |
| 10 | 1·0649 |
| 15 | 1·0993 |
| 20 | 1·1354 |

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| Per-centage of crystallized sulphate of zinc in solution. | Specific gravity of solution at 25° Cent. |
|---|---|
| 25 | 1·1738 |
| 30 (saturated) | 1·2146 |
| 5 | 1·0289 |
| 10 | 1·0588 |
| 15 | 1·0899 |
| 20 | 1·1222 |
| 25 | 1·1560 |
| 30 | 1·1914 |
| 35 | 1·2285 |
| 40 | 1·2674 |
| 45 | 1·3083 |
| 50 | 1·3511 |
| 55 | 1·3964 |
| 60 | 1·4439 |
| 62·1 (saturated) | 1·4650 |

## A DIRECT METHOD OF DETERMINING BATTERY RESISTANCE.

By Dr. Werner Siemens.

Ohm's law enables us to determine the constants of galvanic circuits, that is to say, to measure them in terms of conventional units by measuring the intensity of currents.

But exact measurements of currents are difficult and troublesome to make, even if all the necessary instruments are at hand. It has therefore been the endeavour of electricians to find methods which allow of the direct determination of the constants of the galvanic elements without measurements of currents.

By means of that beautiful arrangement, the Wheatstone's Bridge, the question has been solved in a most satisfactory way for the measurement of the resistance of that part of the circuit in which no electromotive force exists.

Poggendorf succeeded in measuring, by his so-called compensation method, electromotive forces with a degree of accuracy such as is wanted for scientific determinations. His methods were extended by Boscha, Dubois Raymond, and others.

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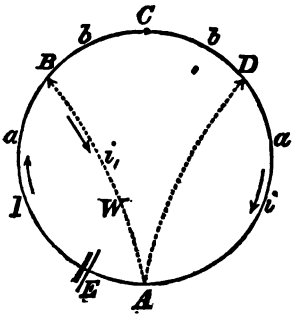
Of late, Waftenhofen and Beetz have shewn that in comparing the electromotive forces of two elements by these compensation methods, introducing known resistances, the data for calculating the resistance of one of the elements may be obtained; and a very neat method has been suggested by Mr. Henry Mance, which was communicated to the Royal Society by Sir William Thomson in January, 1871.

I have now succeeded in finding another method, which recommends itself by its simplicity, by means of which the resistance of a galvanic element, or, in fact, any part of the circuit which contains an electromotive force, can be determined directly, without the aid of an auxiliary battery. This method is similar to Wheatstone's bridge, based on the laws of derived circuits.

Fig. 1.




Let A B C D represent an electric circuit, the aggregate resistance of which is divided into two equal parts, A C = C A = $a$, (A and B); in a distance ($b$) from C, measured in terms of the same unit, is a shunt (B A), having the resistance (W); in the part A B of the circuit is an electromotive force (E). The intensities in the three branches being $I i_1$ and $i$ respectively, the following equations exist according to Kirchhoff's laws:—

I ..... $(a - b)\, I + (a + b)\, i = E$

II ..... $W\, i_1 - (a + b)\, i = 0$

III ..... $i_1 + i = I$

from equation II

$$i_1 = \frac{(a + b)\, i}{W}$$

Inserting this into equation 3 we have

$$I = i + \frac{(a + b)\, i}{W}$$

and inserting this into equation 1

$$(a - b) \left\{ i + \frac{(a + b)\, i}{W} \right\} + (a + b)\, i = E$$

and this gives the intensity in the branch B A

$$i = \frac{E\, W}{a^2 + 2\, a\, W - b^2}$$

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In this equation the value $b$, or the resistance from the electric centre of the whole circuit to the point where the shunt comes in, appears only in the square, that is, the intensity in that branch of the circuit that contains no electromotive force is not altered whether $b$ be positive or negative, or whether the shunt be connected to B or D in our figure, or equidistant in an electrical sense, on either side of the centre C.

In this very simple way the resistance of a galvanic element may be determined directly by sliding a contact along the wire of a Rheostat, and deducting the value of B A expressed in units, from that of D A expressed in the same term, the difference being equal to the resistance of the electromotor.

If the electromotor be a large battery with a considerable resistance, the wire of the rheostat may be replaced by a set of resistance coils, along which the contact slides.

Fig. 2.

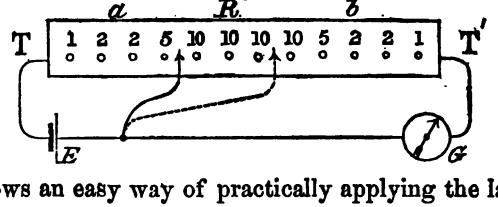


*Fig.* 2 shows an easy way of practically applying the law found by Dr. Werner Siemens, for determining the resistance of a battery.

The Electromotor E, of which the resistance has to be measured, is arranged so that one of its poles is connected to the terminal T of the Resistance box R, on which the brass pieces to which the ends of the Resistance Coils are soldered, are provided with holes in the centre to receive a plug. The coils in this box may be arranged in any way, but very conveniently as indicated in the figure. The other pole of the Electromotor is connected to a shunt terminating in a "wandering" plug, which may be inserted in any of the holes of the resistance box in the centre of the brass pieces, and also through a Galvanometer, G, to the remaining terminal, $T^1$, of the Resistance box, R.

All holes in the latter being unplugged, the "wandering" plug is inserted somewhere between the centre of the Resistance box and that side of it which is connected directly to the Electromotor. The deflection on the galvanometer is to be noted. Then the plug is to be so placed on the other side of the Resistance box that the Galvanometer shows again the same deflection.

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Calling the resistance which was found between the terminal T and the plug, when the first reading was taken, $a$, that between the plug and terminal $T^1$, when the second reading was taken $b$, and the resistance of the Galvanometer, G, we have the resistance of the Electromotor—

$$= G + b - a$$

provided, as already mentioned, that the Galvanometer was in both cases equally deflected.

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## VISUAL TELEGRAPHY.

### SIGNALS OF DISTRESS, &c., IN THE MERCANTILE MARINE.

By Captain P. Colomb, R.N.

The disaster which occurred to the "Northfleet" has directed public attention to the question of signals of distress—especially by night—amongst merchant ships. It has been somewhat startling to the general public to learn that a ship and all on board her may be destroyed within immediate reach of assistance, and in the midst of friends, without having the power to convey the intelligence to one of them, while the time for doing so might have been ample if only the means had been provided.

Though the question is new to the public, it is very old to those who have watched the progress of these events, and it is by no means new to the Board of Trade. That department has had the question thrust upon it, not only by circumstances similar to those of the "Northfleet," but by the converse case, where a loss of life occurred in the attempt to carry succour to a ship which was not really in want of that particular kind of help.

It is comparatively common for ships to be destroyed or injured in various ways from want of power—at night or in fog—of asking either advice or assistance. But it is, perhaps, more common for life and property to suffer from want of means of telegraphing *after* the disaster to the ship has occurred. A very notable instance was presented by the *Rangoon*, which ran on a rock near Point de Galle, and whose signals, meant to express that she was sinking, really conveyed to the minds of the observers the idea that she was speeding some parting guests.

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That such a state of things should now exist, is hardly creditable to modern science, but perhaps one excuse may be found in the thought that the facts are not generally known to men who might devote themselves to supplying the deficiency.

At present, ships of the mercantile marine carry, as a rule, the means of making any want, whatever its nature, known to neighbouring vessels or to signal stations on shore, so long as daylight and clear weather lasts. But at night or in fog, when the necessity for such power presses with double force, they are absolutely precluded from expressing their wants. At this moment such ships are accustomed to use "flare up lights," rockets, blue lights, or even guns, quite indifferently, to express by night all their various wants and distresses, from want of a pilot, or a tug, up to the want of such immediate assistance for the saving of life as was called for in the case of the "Northfleet."

The natural consequence has ensued, that when these signals are seen, only those whose livelihood is gathered by supplying pilotage or steam power, approach the ships making them, and life or property is lost for the want of the particular help required, which is perhaps quite close at hand.

In the Royal Navy these guns, rockets, and blue lights, are also in constant use, but they bear no more signification than they ought to bear. That is, they simply draw attention to the ship which uses them. All sudden wants or distresses are denoted at night, or in fog, side by side with these alarm or attention signals, in words. If a man of-war catches fire, and requires the help of her fellows, she says she is on fire and specifies the sort of help she wants. If she is running into danger unwittingly, her fellows tell her of the danger and how to avoid it. If, like the "Northfleet," she is sinking, surrounded by friends, she tells the state of her case, and asks that boats may be sent to save life.

It is generally supposed that the difficulty in the Mercantile Marine will be met by legislation which shall devise a particular signal denoting "urgent distress," and then, by making its use on trivial occasions a punishable offence, secure that it shall show every observer that urgent distress is suffered by the vessel employing it. But if this idea be examined somewhat closely, it will be found at best to be but a very doubtful remedy for the present evil.

In the first place there is something incongruous in applying

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compulsory legislation to what is, after all, a scientific question. If legislative sanction is required to encourage the use of a new process, instrument, or substance, of which the value is only known to experts, it seems a very legitimate function of Government to give the new thing that much support; and science suffers in no degree from such help. When, however, the new thing is intended to be useful to him who uses it, it almost seems a hindrance to scientific progress for a Government to exercise any power beyond sanctioning its employment, and if a general rule is necessary, announcing what it shall be.

In another view of the question, it may be assumed, either that an urgent distress signal will be so seldom used, that its meaning will not be remembered at the proper time by observers who witness it, or that it will gradually fall to the level of a simple means of attracting attention. The latter possibility is strengthened by the thought that what is at one time a trivial want in a ship, may be at another a matter involving her safety. Unless, therefore, every particular occasion on which a distress signal may be lawfully used is prescribed, the captain of the vessel must be left judge of the urgency of his wants, and the strong probability is that he will generally consider them so urgent as to authorise the use of whatever means may be best adapted to obtain their supply.

It is sufficiently evident that our real aim should be, not the providing of an empirical special signal covering all wants under the general phrase, "Urgent distress," but the supply of the means by which ships of the Mercantile Marine shall be enabled to express their particular wants.

These means are now, by international arrangement, made applicable to the ships of all nations, by the use of the ordinary coloured flags in the day-time. It may be debated whether simpler and more efficient means might not be had, for there is, after all, a good deal of trouble and inconvenience in the use of flags for the requirements of merchant ships; but, so far as it goes, there can be no doubt of the advantages conferred by the plan. A more immediate object for the Telegraph Engineer than the improvement of signalling between merchant ships in the clear daylight, should be devising means for communicating at night, and in fog. It is impossible to say for certain, without trial, whether the means used in the English and many foreign navies will be found ultimately available for the mercantile marine, but whatever arrangements become successful which are of the nature of visual or

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audible signals, it may be prescribed for them that they must be extremely simple; easily mastered, and easily retained in the memory; they must attract attention very easily—much more easily than anything now used in merchant ships; they must not involve preparation beforehand, nor time in their display. It is probable, also, that they must be such as to come naturally into constant use, because it is a known fate of all special arrangements to be either absent or overlooked when the occasion for them arises.

We should, in short, make a very considerable advance in nautical telegraphy, if we could supersede the methods of attracting attention now in ordinary use afloat, by some plan which would not only attract attention, but express the particular want to which that attention is required.

## ON LIGHTNING CONDUCTORS.

By James Graves.

Abstract of "Communication."

The author says people always speak of lightning "falling," and never "rising" or "ascending from the earth," and which, he thinks, must often be the case.

A cloud is equally charged throughout, and so soon as this charge is sufficient to break through the intervening air the flash occurs, when "the disturbed equilibrium" is restored, viz., "a certain quantity of positive separated from its equal quantity of negative—both by induction kept at the same tension; each straining itself to the utmost of its power to join its opposite and imprisoned companion."

The author adopts the dual theory of two electricities, and not the Franklinian theory of one electricity; "Lightning is the joint work "of the positive and negative electricity. When the proper conditions "obtain between the earth and the cloud for the production of a "flash, then both the positive and negative exert their utmost to "approach each other," selecting the easiest available channel, such as trees, bell-wires, church-steeples, &c.

He recommends erecting numerous lightning conductors everywhere, especially upon high hills and high buildings, to conduct the negative electricity upwards as near to the clouds as possible, so as to bring about the "amalgamation" of the two electricities harmlessly.

He describes a tree struck by lightning, in which the bark of the lower 40 feet of the tree was stripped off, the track of the discharge

down the tree was deflected at a sharp angle by a knot of harder wood than the rest of the tree. The stripping of the bark he atributest to the conducting power of the descending sap, which, being volatilized, tore off the bark. Above the 40 feet line, the track of the flash was distributed amongst the branches from which he infers that the action was upward from the roots towards the branches.

## ON A NORMAL RESISTANCE THERMOMETER.

(Extract of Letter communicated by Mr. R. S. Culley, Vice-Pres. S.T.E.)

London, 14th *February*, 1873.

Dear Sir,

I have to acknowledge the receipt of your letter to me of the 11th instant with reference to the subject of thermometers for the purpose of measuring the temperatures of various parts of the pumps, ducts, and containers of the new extension of your pneumatic lines.

The system which I am of opinion you would find to give the most accurate results with the least trouble is that of a form of resistance thermometer modified in such a way as to obtain direct readings of temperature without having to make reductions.

Mr. C. W. Siemens, whose name is, in so distingushed a manner, associated with this subject, has proposed several very beautiful forms of resistance thermometers with which I have had a good deal of experience. They are, however, not *normal* Instruments; but as hitherto constructed they are *secondary* apparatus depending upon readings taken directly from mercury thermometers, or upon coefficients determined originally by means of mercury thermometers. They, in fact, hold, in relation to mercury thermometers, only the same position which aneroids do to Mercury Barometers; whatever errors are incidental to the one being necessarily reproduced by the other.

It appears to me that an electric resistance thermometer, in order to be a normal physical instrument, would have to fulfil all the following conditions:—

1. Its graduation must be *independent;* that is to say be done without the help of any other thermometer, in fact, as if no other thermometer had ever existed.

2. The readings of temperatures must be direct and free from any reference to the co-efficients of the metals used in its construction.

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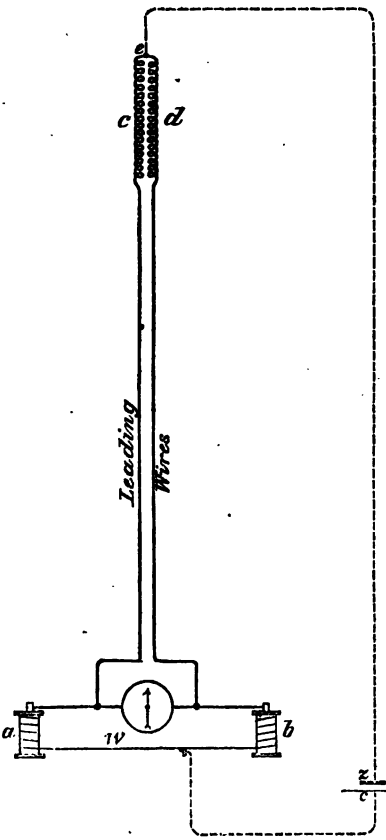
3. Its indications must be totally unaffected by the temperature of the measuring apparatus.

I have recently subjected to a series of experiments, a plan by which all these conditions may be easily obtained, and have succeeded in producing a resistance thermometer independent of the co-efficients of its constituent metals, and infinitely more delicate and exact than any thermometer constructed of glass and mercury can be. This modification is as follows:—

Instead of making the thermometer coil of a single metal to form one side of the Wheatstone balance, and forming the other three sides by three resistances of the measuring apparatus as has hitherto been done when using the balance, I put half the balance into the thermometer, and keep the other half only in the testing room; by which arrangement the effect of temperature of the measuring apparatus is entirely eliminated. The half of the balance forming the thermometer, I make (1) of a metal having a high coefficient, and (2) of an alloy having a low coefficient of increment of resistance with temperature. In making up this thermometer, I take two lengths of wire, *c.* and *d.*, whose resistances are nearly equal, and wind them together upon a common spool, connecting their ends together in the point, *e.*, with an earth or return circuit containing a battery and key. The other ends of the two wires are connected to insulated leads whose resistance is made inappreciably small in comparison with that of the coils.




The measuring apparatus consists simply of a bisected wire. In order to render thermometric readings with it convenient, I

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coil up its two ends on spools. The middle portion *w.* (on which the readings are taken), is provided with a scale and a travelling (bisecting) contact; the end portion on *a.*, is about $3\frac{3}{4}$ times as long; and the portion *b.*, about 3 times as long as *w.* With this relation supposing the coil *c.* to be made of a pure metal, and *d.* of german-silver or platinum-silver alloy, (the resistances of the two being nearly equal at the mean temperature of the air), the bisecting contact on *w.* will stand a short distance from one end, in order to balance the galvanometer needle, when the thermometer is placed in melting ice; and a short distance from the other end when it is in boiling water.

These two points on the scale being exactly noted, it is only necessary to subdivide the space between them into 100 equal parts, in order to have an independent centigrade thermometer. Each degree of which shows the point where the bisecting contact must stand in order to balance the galvanometer when the coils *c* and *d*, have the corresponding temperature.

The materials which I prefer for the construction of this thermometer are, 1st. a pure metal or a commercial metal as nearly pure as can be had, in order that its resistance may increase as much as possible with heat; and 2nd. an alloy whose resistance increases as little as possible with heat.

I do not consider copper so good a metal as platinum to make resistance thermometers of; because, whilst its percentage increment is nearly the same, its conducting power is so much higher that a larger mass of the metal is necessary, which may, to some extent, prevent it responding quickly to small changes of temperature. For the second coil of the thermometer, Matthiessen's alloy of platinum and silver is well adapted because its percentage increment is very low, it has a low conducting power, and is very constant.

In order that this resistance-thermometer be an exact measure of temperature, it is necessary that the curves of the metal and alloy *separate uniformly;* that is to say, the percentage increment of the platinum at $t°$ must be in the same proportion to that at 100°, as the percentage increment of the alloy at $t°$ is to that at 100°.

The formula for the conducting power of commercial platinum given by Matthiessen * is

$$\lambda = 11{\cdot}708 - 0{\cdot}081875\,t + 0{\cdot}00006762\,t^2,$$

and that for his platinum-silver alloy † is

$$\lambda = 6{\cdot}7032 - 0{\cdot}0022167\,t + 6{\cdot}000001394\,t$$

* *Phil Trans.* 1864, p. 195. † *Brit. Assoc. Report*, 1862, p. 137.

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Now when a resistance-thermometer is constructed according to my method, with two coils (commercial platinum and platinum-silver alloy) wound together, and each having 1,000 ohms resistance when at 0° C., their conducting powers and resistances at different points of the thermometric scale (assuming Matthiessen's figures to be correct) are as follows:—

| Temp. | Platinum. | | | Pt.—Silver Alloy. | | |
|---|---|---|---|---|---|---|
| | λ | Resistance. | Increment per cent. | λ | Resistance. | Increment per cent. |
| 0° Cels. . . | 11·708 | 1000·0 | — | 6·7032 | 1000·0 | — |
| 25° „ . . | 10·953 | 1068·9 | 6·89 | 6·6487 | 1008·2 | 0·82 |
| 50° „ . . | 10·283 | 1141·2 | 14·12 | 6·5951 | 1016·3 | 1·62 |
| 75° „ . . | 9·698 | 1207·3 | 20·73 | 6·5448 | 1024·2 | 2·42 |
| 100° „ . . | 9·197 | 1273·1 | 27·31 | 6·4954 | 1032·0 | 3·20 |

The curve of the metal is evidently much steeper than that of the alloy, but it is similar in its nature or very nearly so, according to the above formulæ, as you will see by the following table, col. 2 of which gives the resistances of the alloy calculated by Matthiessen's formula, and col. 3 the resistances of the alloy calculated from those of the platinum coil, supposing the curves of the two to separate uniformly.

| Temp. | Calculated Resistance of Alloy. | | Difference Per Cent. |
|---|---|---|---|
| | By Matthiessen's Formula. | From Platinum Formula, supposing curves separate uniformly. | |
| 0° Cels. . . . | 1000·0 | 1000·0 | — |
| 25° „ . . . | 1008·2 | 1008.1 | 0·01 |
| 50° „ . . . | 1016·3 | 1016·5 | 0·02 |
| 75° „ . . . | 1024·2 | 1024·3 | 0·01 |
| 100° „ . . . | 1032·0 | 1032·0 | .. |

The greatest difference between these two curves is in the middle (about 50°, where it amounts to very nearly 0·02 per cent. Now, as an increase of 100° makes a difference of about 24 per cent. between the resistances, a difference of 0·02 per cent. will occasion a discrepancy of only about 0·08 degrees centigrade.

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But as each of Matthiessen's curves was determined from only three temperatures [the platinum at 9°, 54·5°, and 100 and the alloy at 8·27, 54°, and 99·9], I do not think that they are likely to be exact within this limit.

Whether this decrepancy is due to an error to this extent in Matthiessen's formula, or to any real difference in the nature of the curves for the metal and alloy remains to be determined. It is, however, clear that within this limit of error a differential resistance thermometer may be made and independently graduated, without any direct or indirect aid from any other thermometer, and, therefore, that it may be to this extent considered a normal instrument. And it has this decided advantage that the values of neither the resistances, nor the coefficients of its constituent metals, are required to be known.

* * * * * *

I am, dear Sir,

Yours truly,

R. S. Culley, Esq, C.E., ROBERT SABINE.

Engineer-in-Chief, Postal Telegraphs.

## RESISTANCE OF WIRES.

By James Graves.

In a foot note on page 22 of No. II. of the *Telegraphic Journal*, it is stated that "it is open to future investigation to determine whether a "body which offers a unit of resistance to one cell, offers neither more "nor less than a unit of resistance to a hundred cells."

Since reading this I have accurately adjusted two separate ohms of No. 20 German silver wire, and used them as a Wheatstone's Bridge.

As a first experiment I put on the third side of the parallelogram a resistance of four hundredths of a Varley unit (0.04 v.u.) and on the remaining side 1.1 ohm. by Varley. These exactly balanced each other with 1 cell, 50 cells and then 1 cell again, not a shadow of difference being observed on the galvanometer, which was a very delicate astatic mirror, whose resistance was 5,854 ohms.

Secondly, I increased the resistance on the third side to 0.81 v.u. which exactly balanced 20.6 ohms, and this arrangement gave the same result with 1 as with 50 cells.

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As the resistance of the galvanometer, being very high in comparison with the four branches of the parallelogram, might account for this result, I prepared a mirror galvanometer, bound with 4 yards of No. 16 copper wire, having a resistance of about six hundredths (0.06) of an ohm.

With the same bridge of equal ohms, I took a length of 30 inches of No. 18 copper wire for the third and fourth sides, and following the bight round I found a spot at which the balance was perfect; the addition of one-tenth of an inch either side of this spot gave a perceptible deflection. I then measured the lengths of the two halves, and found them exactly 15 inches each between the points of contact. With one cell or with 50 cells, the result was precisely the same. Two sides of this parallelogram were of German silver and two of copper; they would, therefore, be equally affected thermally.

In another experiment I used the same bridge and galvanometer. On the third side I placed half an ohm of German silver, and on the fourth side a length of No. 24 copper wire sufficient to make a perfect balance with momentary battery contacts. This gave the same result with one as with 50 cells, alternated three times with an interval between.

With this same arrangement, one cell in permanent contact three minutes showed no alteration; 50 cells on three minutes gave evidence of slight motion, which by making and breaking could be increased to an oscillation in the direction of an increase in the copper side, showing the unequal effects of heating. Practically, as far as these experiments show, a standard unit of resistance remains the same for low as well as for high power.

Valentia, Dec. 19, 1872.

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## ON THE MEASUREMENT OF THE INTERNAL RESISTANCES OF BATTERIES.

By H. R. Kempe.

Having had occasion a short time ago to make some experiments which necessitated the accurate knowledge of the internal resistance of a battery employed (100 Daniell's elements) I found some difficulty in obtaining the resistance with any degree of accuracy by

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means of the usual methods. With an ordinary tangent galvanometer, adopting the method of halving the deflection, no apparent effect was produced on the needle with a considerable variation in the resistance in circuit; and even when great care was taken, there was almost invariably a different value obtained on repeating the experiment. On account of the high power of the battery it was impossible to work with a more sensitive galvanometer. After a large number of experiments, I found the following method gave very accurate results, and was, at the same time, very easily made:—The tension of the battery was first measured by the discharge of a condenser through a Thomson galvanometer. A shunt was then introduced between the terminals of the battery and a second discharge reading taken. Calling $\alpha^\circ$ the first reading, and $\beta^\circ$ the second reading, S the resistance of the shunt, and $x$ the resistance of the battery, we get the proportion—

$$\alpha^\circ : \beta^\circ = x + S : S$$

that is
$$x = S\,\frac{\alpha^\circ - \beta}{\beta^\circ}$$

if S is adjusted until

$$\beta^\circ = \frac{\alpha^\circ}{2}$$

then
$$x = S$$

which gives the resistance of the battery without calculation.

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# ABSTRACTS AND EXTRACTS.

## ON THE ACTION OF ELECTRICITY ON GASES.

By Sir C. B. Brodie, Bart., F.R.S., Hon. D.C.L. Oxon.

This memoir which is intended to be the first of three communications as to the action of electricity on gases, is devoted to the consideration of the changes produced by the action of electricity on oxygen gas as estimated by the changes thus effected in its chemical properties.

The memoir is divided into four sections.

Section I. contains an account of the methods employed for generating, collecting, and preserving the electrized gas, and also of the measuring-apparatus employed for estimating the changes in the volume of the electrized gas, effected in the various experiments subsequently described.

The gas, carefully dried, was submitted to the action of electricity by causing a current of the gas to pass through the induction-tube of Siemens, the interior of which was filled with water or (where a low temperature was desired) with a saline solution. The tube was placed in a glass cylinder containing water or a refrigerating-mixture. The interior and exterior of the tube were respectively connected with the terminals of a powerful Ruhmkorff's coil. The electrized gas, after its passage through an induction-tube, was collected, in a gas-holder of peculiar construction, over concentrated sulphuric acid. It may be thus preserved for several hours without sensible variation in its properties.

The principle employed for the measurement of the gas in which it was desired to estimate the changes in volume produced by the experiment, was the principle of pipette-measurement which has been so successfully employed by chemists for the measurement of liquids. In this way a considerable volume (say from 250 to 300 cub. centims.) may be measured with facility and precision. A definite volume of gas was thus always operated upon.

The gas having been measured in the pipette was drawn over by means of a mercurial aspirator, an instrument which served the double purpose of an aspirator and measuring-apparatus. The principle of this aspirator that was originally employed in the apparatus of Regnault for measuring the volumes gases, namely the estimation of the pressure and temperature at which the gas occupied a known space, from which the volume of the gas at standard temperature and pressure was calculated. By means of this apparatus a change

in the volume of the electrized gas, to the extent of about 1 part in 1,000, could be accurately estimated; that is to say, after the calibration of the apparatus, 1,003 volumes of gas as measured in the pipette were found to measure 1000·7 volumes in the aspirator. These numbers represent the errors of the experiment, and any differences in the volume of the gas beyond this limit must be considered to be due to the experiment to which the gas was submitted. The pipette and the aspirator were placed on a table, separated by an interval of about 8 or 10 inches.

In section II. the results are given of passing the electrized gas through a solution of neutral iodide of potassium, also of heating the gas, of passing the gas over metallic silver, copper, gold, aluminium, and binoxide of manganese, and of the decomposition of a solution of binoxide of sodium effected by the passage of the gas, a quantitative estimation of the changes in the volume of the gas and the oxidation effected being in all cases made.

The precision attained in such experiments may be estimated by the results of the measurement of the gas before and after its passage through a solution of neutral iodide of potassium. As the mean of eight concordant experiments, 100 cub. centims. of gas, as measured in the pipette, were found after the experiment to measure 99·93 cub. centims. in the aspirator. An oxidation was effected in the solution of neutral iodide of potassium equivalent to 3·77 cub. centims. of oxygen; that is to say, 3·77 cub. centims. of oxygen were thus removed from the gas without an appreciable variation in its volume. The volume of the gas thus absorbed by neutral iodide of potassium was in subsequent experiments assumed as the unit to which other analogous variations were referred.

When the electrized gas is passed through a solution of binoxide of sodium an increment occurs in the volume of the gas. Thus in two experiments the increment in the volume of the gas, as estimated from the difference of the volumes in the pipette and the aspirator, was 1·93, 1·99, the "titre" of the gas (as just explained) being taken as 1; and the ratio of the sum of the oxygen lost by the binoxide of sodium (as estimated by titration of the solution of binoxide of sodium before and after the experiment with permanganic acid) and the titre of the gas to the titre of the gas was in the same experiments 2·06, 2·17. In two other experiments this same ratio was 2·00, 2·08,—the reaction being analogous to the decomposition of binoxide of sodium by ferrocyanide of potassium, and of binoxide of hydrogen by permanganic acid, previously investigated by the author.

Section III. comprises an account of the action of the electrized gas upon a solution of hydriodic acid, strongly alkaline hyposulphite of soda, polysulphide of sodium, and other substances.

In the case of the passage of the gas through a solution of hydriodic acid, the oxidation effected (after a certain degree of concentration of the acid has been attained) is exactly twice the oxidation effected by the same gas in a

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solution of the neutral iodide of potassium. The mean of 33 such experiments gave 1·99 as the amount of oxygen employed in the oxidation of the hydriodic acid as compared with the "titre" of the gas. The individual experiments exhibit no inconsiderable differences; but the probable error of the result, as estimated by the method of least squares, is 0·02; that is to say, from these experiments alone, without introducing any hypothetical considerations whatever, it is an equal chance that the true value of the ratio sought lies between the values 2·01 and 1·97. The value indicated by chemical theory is 2, with which theory, therefore, the experiments agree.

The action of the gas upon a strongly alkaline solution of hyposulphite of soda is precisely of the same character. The volume of gas was measured before and after the experiment; and a contraction was found to occur equal in amount to the "titre" of the gas. The mean of twenty-two experiments gave 1·33 as the amount of this contraction. The peculiar oxidizing properties of the ozone are entirely destroyed by its passage through the solution; and it is to be inferred that while the diminution in volume is equal to the "titre" of the gas, the oxidation effected in this, as in the previous case, is the same as that which would be effected by a volume of oxygen equal to twice the "titre" of the gas.

Experiments made with a solution of polysulphide of barium gave a similar result.

Section IV. comprises various experiments made with the solution of neutral and slightly alkaline hyposulphite of soda, with oil of turpentine, and with protochloride of tin.

The experiments with neutral and slightly alkaline hyposulphite of soda were conducted precisely in the same manner as the experiments described in Section III. with the strongly alkaline hyposulphite. The result, however, is very different, the contraction in this case being equal in amount to twice the "titre" of the gas. The mean of 17 experiments made with the neutral hyposulphite gave 2·02 as the value of this contraction; and the mean of 10 experiments made with the slightly alkaline hyposulphide gave for it the same value.

It is hence to be inferred that the oxidation effected in these cases is equa in amount to three times the oxidation effected by the same gas in neutral iodide of potassium.

Similar experiments made with oil of turpentine entirely confirmed the view of Soret as to the amount of contraction which the gas undergoes when acted upon by this substance, the means of eight experiments giving 2·02 as the value of the contraction.

The investigation of the effect due to the action of the electrized gas upon protochloride of tin is attended with considerable difficulty, from the circumstance that a solution of protochloride of tin is readily oxidized by the action of pure oxygen. The difficulty was met in two ways, both of which led to the

same conclusion, namely:—by applying a correction for the oxidation effected by the oxygen with which the oxone was associated; and by using very dilute solutions of the protochloride of tin, in which this oxidation is reduced to a minimum. In two experiments conducted on the latter principle, and in which the oxidation, as well as the contraction, was experimentally determined, the value of the contraction was found to be 2·12 and 2·33, while the oxidation in the two experiments respectively was 3·12 and 3·07.

Using the notation employed by the author in a previous communication * to the Royal Society, and putting $\xi^2$ as the symbol of the unit (that is of 1·000 cub. centim. at 0° and 760 millims.) of oxygen, and putting $[\xi]$ as the symbol of that simple weight $\xi$ transferred to the oxidized substance in the various oxidations effected by the ozone, and further assuming that ozone is to be regarded as some denser form of oxygen, to the unit of which the symbol $\xi^{2+n}$ (where $n$ is a positive integer) is to to be assigned, the result of the total system of experiments of which the account is given in this memoir may be expressed, so far as regards the distribution of the matter of the unit of the ozone, in the various reactions by the general equation

$$(p+q\,\xi^{2+n}=q\,\xi^2+(p\,(2+n)+q\,n)\,[\xi],$$

where $p$, $q$, $n$ are positive integers.

The investigation of the various hypotheses originating in this equation leads to the conclusion that the hypothesis that the unit of ozone is composed of there simple weights, $\xi$, and is to be symbolized as $\xi^3$, is both necessary and sufficient for the explanation of the total system of phenomena, and that no other hypothesis of the order referree to is tenable.—Proceedings of the Royal Society.—*Philosophical Magazine.*

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## ON THE MEASUREMENT OF THE INTENSITY OF CURRENTS BY MEANS OF THE ELECTROMETER. BY M. E. BRANLY.

When a wire is traversed by a voltaic current, its different sections present different charges of static electricity. A and B being two points in the conductor, $a$ the electric potential in A, $b$ the potention in B, the difference $a-b$ is proportional to the intensity of the current. This is expressed by Ohm's formula

$$i=C\frac{-b}{r}$$

C is a constant; $r$ represents the resistance of the part AB. If the wire is cylindric and homogeneous, the electrical density at each point (quantity of electricity on the unit of surface) is proportional to the potential.

The proportionality between the difference of potential and the intensity is easy to verify by means of the mirror-electrometer which I described in a

* *Vide* "Calculus of Chemical Operations," by Sir B. C. Brodie, Bart., F.R.S., Phil. Trans. 1866, pp. 781—852.

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communication on the 19th of February last. One of the pairs of sectors of the electrometer takes the same potential as A, and a quantity of electricity proportional to that potential; the other pair takes the same potential as B.

Between the poles of a pile, liquid or metallic resistances were interposed; Pouillet's tangent-compass gave the intensities for the strong currents, Weber's for the feeble ones. The electrometer measured the differences of potential or tension * corresponding to the extremities of various coils of known lengths of telegraphic wire. The results which follow are referred to a kilometre of wire, equivalent to 100 metres of Pouillet's unit (a column of mercury of 1 metre length and 1 millim. section.

The difference between the two poles of a Daniell's element, open, is represented by 100.

| Electrometer. | | Compass. | | | |
|---|---|---|---|---|---|
| Deflections. | Ratio of one deflection to the following. | Pouillet's. | Weber's. | | Ratio between two successive tangents. |
| | | | 1 turn of wire. | 10 turns. | |
| 146 | 2·18 | 43° 42′ (tan = 0·956) | ..... | ..... | 2·18 |
| 67·66 | 1·680 | 23 15 (tan = 0·429) | ..... | ..... | 1·677 |
| 40·34 | 1·44 | 14 18 (tan = 0·255) | ..... | ..... | 1·50 |
| 28 | 2·99 | 9 39 (tan = 0·17) | 63·67 | ..... | 3 |
| 9·37 | 2·366 | ..... | 21·22 | ..... | 2·358 |
| 3·96 | 2·414 | ..... | 9 | 86·4 | 2·383 |
| 1·64 | | | | 36·25 | |

The current being produced by eight fresh Daniell's elements, the number given by the electrometer shows in each case the total resistance of the circuit expressed in kilometres. It was $\frac{800}{146}$ in the first measurement, $\frac{800}{67·6}$ in the second†.

If from time to time we make a comparative measurement at once with an electrometer and a tangent-compass in the preceding conditions, the numbers given by the compass, multiplied by a coefficient, will show the difference between the tensions corresponding to the extremities of 1 kilometre of wire; we shall thus have the exact value of the total resistance of the circuit, if the elements employed are fresh. That value will only be approached if the electromotive force of the pile has diminished.

The use of the electrometer for the determination of the intensities of currents is known; the results obtained at different periods are comparable if we are

* This word "tension" is generally employed in the case in which the expression "potential" will be adopted.

† I suppose here that the electromotive force of a Daniell's element does not change when the current passes. Direct experiments have shown me that it is, except one per cent., the same when the circuit is open and when it is closed with as little external resistance as possible.

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careful to measure at the same time the difference of the tensions at the two poles of a Daniell's element.

The Daniell's element gives constant differences between its two poles when it is constituted in the following fashion:—a vessel containing a plate of amalgamated zinc and a saturated solution of sulphate of zinc; a second vessel with a saturated solution of sulphate of copper; a U-tube containing sulphate of zinc, and closed at its extremities with gold-beaters skin, puts the two vessels in communication.

In the formula $i = C\frac{a-b}{r}$, let $C = 1$; the current having the unit of intensity will be that for which the difference of the potentials at the two extremities of the unit of resistance is equal to the unit of electric potential.

The unit of potential is the potential of a sphere, charged with the unit of electricity*, whose radius is equal to the unit of length.

If we take for the unit of intensity, the intensity of the current which produces at the two extremities of 1 kilometre of telegraphic wire a difference of tension equal to one-hundredth of that which exists between the two poles of a Daniell the intensities of the currents in the above reported experiments will be 146, 67·6, 40·34, &c.

But, in order to give more generality to the definition of the unit of intensity it is expedient to value in electrostatic units the potential at one of the poles of a Daniell's element when the other pole is connected with the earth.

If the pole of the pile is put in communication by a long wire with a sphere of radius 1, this sphere takes the same potential as the pole of the pile, and the quantity of electricity on its surface expresses the potential of the pole.

The measurement was made with a torsion-balance, which was constructed as follows. A moveable gilt ball was fixed at the extremity of a rod of gum lac which was supported by a torsion-thread; this last was in metallic communication with the ball. A fixed ball, of the same diameter as the other, was, borne by a stick of gum lac; and a fine thread connected it externally with the prolongation of the torsion thread. The centres of the two balls were at first placed at a certain distance (about 3 centims.) without there being any torsion.

The two balls were at first connected with each other and with the earth: afterwards they were charged permanently by the negative pole of a pile of Daniell's elements, the positive pole being led to the earth.

Here are the details of an experiment, the units adopted being the millimetre and the milligramme:—

| | |
|---|---|
| Position of equilibrium of the moveable ball (the two balls connected together and with the earth) ... ... ... | 83 |
| The two balls communicating with the negative pole of a pile of 65 Daniell's elements ... ... ... ... ... | 178·5 |
| The communication with the earth re-established ... ... | 82·75 |

178·5—82·87—95·63.

* The unit of electricity is the quantity which, acting upon an equal quantity placed at the unit of distance, viz. 1 millimetre, produces a repulsive force of 1 milligramme.

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The equation $\frac{q^2}{d^2} l \cos\frac{\alpha}{2} = n\phi$ gives the quantity $q$ of electricity which is found on each ball.

$d$ is the distance between the two balls. To find its value, a telescope placed at a measured distance permitted the angle to be measured under which the centres of the two balls were seen; $d = 32{\cdot}6$ millims. when the two balls communicate with the negative pole of the pile.

$l$, length of the gum-lac spindle, 70 millims., reckoned from the point of suspension from the torsion-thread to the centre of the ball.

$n$ represents the force necessary to twist the thread an arc equal to the radius. This quantity is obtained by causing the thread to oscillate after replacing the stick of gum lac by a metallic spindle of known weight and length. The thread of the balance was 30 centims. long; $n = 5{\cdot}47$; with the units employed it required a force of 5·47 milligrammes, applied at the distance of 1 millim., to twist the thread an arc equal to the radius.

$\phi$ is the angle of torsion. The rule being divided into millimetres and placed at 3·13 metres from the mirror $= \frac{95{\cdot}63}{3130}$.

$\alpha$, the distance-angle

$$\frac{\alpha}{2} = 13^\circ\ 28'; \quad \cos\frac{\alpha}{2} = 0{\cdot}97$$

We obtain $q^2 = 2{\cdot}77$, $q = 176$ This is the quantity of electricity which was found upon each of the two balls. The potential will be $\frac{q}{r^2}$; $r$, the radius of one of the balls, 8·3 millims.; $\frac{q}{r^2} = 0{\cdot}0255$. $\frac{q}{r^2}$ therefore represents the density of the electricity distributed upon the sphere, taking for unit of surface in measuring the density the surface of the sphere which has the unit of length for its radius.

In this case a sphere of 1 millim. radius, communicating with the negative pole of the pile of 65 elements, is charged with a quantity of electricity which produces upon an equal mass concentrated at the distance of 1 millim. a repulsive force of 0·0255 milligr. With a single Daniell's element, the density on the sphere of 1 millim., put in communication with the pole, would be only the sixty-fifth part of this, or 0·00039.

This number 0·00039 measures in electrostatic units the difference of potential at the two poles of a Daniell's element constituted as indicated above

To assure myself that the balance worked properly, I ascertained, by connecting the two balls with different series of Daniell's elements, that the results found were proportional to the number of the elements.—*Comptes Rendus de l'Acad. des Sciences*, Aug. 12, 1872, p. 431-435.—*Philosophical Magazine.*

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## ON THE DISTRIBUTION OF MAGNETISM.

By M. JAMIN.

AT the last Meeting of the Academy, M. Trève communicated a note on magnetism, in which he states, among other things, that the poles of a magnet are displaced, being removed from the extremities, when an armature of soft iron is applied. He believes he demonstrates this by placing opposite to the magnet a magnetized needle, by showing that its direction changes after the application of the contact, and by supposing that the pole is in the prolonged direction of the needle.

We ought first to define the word *pole;* we must then remark that, in this experiment, the magnetized needle is submitted to the attractive action of the steel which forms the magnet, of the iron which constitutes the contact, and, again, to the attraction or repulsion of the free magnetism of the magnet. Its direction is along the resultant of these actions—a resultant evidently very complicated, depending on the distance, the weight, and the form of the contact: it is clear that the direction of this resultant cannot lead to any precise conclusion.

What is necessary to determine here is the distribution of the magnetism in the magnet, both before and after the application of the contact, this is a question with which I have long occupied myself, and on which I will now say a few words.

I study this distribution by two mutually corroborative processes. The first consists in placing upon a point of the magnet a small electromagnet of soft iron enveloped in copper wire which communicates with a galvanometer, and suddenly pulling it away. An induction-current is produced, a galvanometric deflection; and from the magnitude of the arc of impulsion I can calculate, after a suitable graduation, the magnetic intensity at the point touched.

The second process, analogous to Coulomb's, consists in placing on the point one wishes to study a small sphere of soft iron supported by a spring, which is stretched progressively till separation takes place. Its tension at that moment is proportional to the square of the magnetism at the point of contact.

If the magnet has its extremities free, it is ascertained that the free magnetism increases gradually from the neutral line to the extremities. The curve of the intensities is very near that indicated by Coulomb. When a contact is applied, all is changed: two poles make their appearance at the two extremities of the contact; the free magnetism of the magnet partially disappears; it augments with the distance to a maximum, to decrease afterwards towards the middle line of the magnet. The conditions of these modifications are very complicated, and merit a very close study. They contribute to the production of the changes of direction of the needle examined

by M. Trève; but in no case can these changes reveal the distribution of the magnetism in the bar, and they cannot be summed up by saying that the poles of the magnet have changed their position.—*Comptes Rendus de l'Académie des Sciences*, vol. lxxv. pp. 1572, 1573.—*Philosophical Magazine.*

## ON ELECTRO-MAGNETISM.

By M. Treve.

It is known that steel needles can be magnetized by discharges from a Leyden jar passing through a wire running round them; consequently static electricity has in this case the same properties as dynamic currents. This property belongs also to Ruhmkorff's induction-coil when its currrents are caused to pass in a *glass solenoid* containing a rarefied gas.

I placed in the axis of the solenoid some bars of steel, which a single discharge was sufficient to transform into magnets. This was a thing foreseen. But though this experiment establishes no new fact, it is perhaps of a kind to make comprehensible the phenomenon by means of which Ampère completed his theory of terrestrial magnetism. Indeed, suppose we make the glass solenoid big enough to envelop the earth, and cause currents from an induction-machine to pass through it, we shall magnetize everything nagnetic found there, and all needles will be deflected in proportions variable with the intensity of the current.

I think we have here a tolerably correct picture of the electrified gaseous currents which, according to Ampère, incessantly circulate round our globe from east to west, forming as it were an immense coil that acts on the variable horizontal vertical currents.—*Comptes Rendus de l'Acad. des Sciences*, vol. lxxv. p. 1624. *Philosophical Magazine.*

## REPORT ON A MEMOIR BY MM. F. LUCAS AND A. CAZIN, ON THE DURATION OF THE ELECTRIC SPARK.

By Edm. Becquerel.*

Mm. F. Lucas and A. Cazin purpose to estimate the duration of electric sparks in some determinate circumstances, especially when the dimensions of the exciting batteries are changed, and the exploding distance, the nature of the electrodes, and the resistance of the circuit traversed by the electricity are varied.

Two methods have hitherto been employed to render appreciable the

* The experiments were repeated before the members of the Commission (MM. Morin, Le Verrier, Fizeau, Jamin, and the Reporter, Edm. Becquerel), at the Conservatoire des Arts et Métiers.

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duration of a spark. One, devised by Wheatstone, consists in causing the image of the spark to be reflected upon a mirror moveable about an axis parallel to the length of the spark. Although the spark of an ordinary electrical machine exhibits no duration appreciable by this means, yet, with a certain velocity of rotation, battery-discharges give images elongated in the direction of the rotation of the mirror, a proof of a sensible duration, but with diminution of luminous intensity. With the aid of this mode of experimenting, M. Feddersen has been able to study the constitution of the discharge, and even its subdivisions.

The other method, given by Arago for the purpose of getting a limit of the duration of lightning-flashes, requires the employment of a disk moveable about an axis perpendicular to its plane. This disk is divided into sectors by radiating lines with equal intervals, and appearing bright upon the darker ground of the disk. From the widening of the lines produced by the light of the sparks their duration may be estimated when the velocity of rotation of the disk is known. This process of experimentation has been followed by M. Felici, who studied by transmission the widening of the transparent lines of an opaque disk, illuminated by the discharges of a Leyden jar, when divers circumstances of their production are varied.

MM. Lucas and Cazin have employed a method which permits easier measurements, and in certain cases more precise, than the preceding, but without distinguishing whether the sparks result from one or several successive discharges. It consists in using a moveable disk, the margin of which, intended to be viewed by transparency, is interposed between the observer and the spark to be studied. This disk, formed of plates of mica, bears on its margin transparent equidistant lines as fine as possible, obtained by photographic reproduction. It is placed in front of a second disk, opaque, of the same diameter, which remains fixed, and has on its margin seven transparent lines including six divisions, the breadth of which corresponds to that of five divisions of the moveable disk, so that this second disk forms a vernier by means of which $\frac{1}{5}$ of a division of the first can be estimated. This vernier constitutes the very ingenious novelty of the method.

The electric spark studied explodes in the focus of the lens of the collimator, which sends rays, parallel to the axis of rotation of the moveable disk, upon the lines of the fixed vernier. A telescope on the other side of the disk permits the observer to examine the luminous appearances.

If the spark has an inappreciable duration, the observer will see only a single bright line or none. In the first case the spark has flashed at the moment of coincidence of a line of the moveable wheel and a line of the fixed vernier; in the second case the spark took place between two coincidences.

The probability of coincidence, which depends on the breadth of the lines of the disks, as well as on the number of the lines on the vernier, has been determined by experiment, and has been found to be equal to 0·70; that is to

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say, if an instantaneous spark be produced at any instant whatever, it will illuminate a line 70 times out of 100, and 30 times not. The probability might be different with another apparatus.

Let us now suppose the duration of the spark to be a little greater than that of the passage of a line of the moving wheel over two lines of the vernier; then, if the spark commenced at the instant of the first coincidence, by reason of the persistence of luminous impressions on the retina the bright line resulting from this first coincidence will be visible at the same time as that from the second, and we shall see two lines at once. If with the same duration the spark bursts forth between two coincidences, it has ceased when the third arrives, and only one bright line is seen, corresponding to the second. On this supposition, therefore, we ought to see one or two coincidences of bright lines at the time of appearances of the discharges.

But if the duration of the spark is a little longer than the preceding, it will be comprised between two numbers easy to determine, the difference of which is equal to the time which elapses between two successive coincidences. Meanwhile the approximation can be carried further; and the authors have shown that, in consideration of the above-mentioned probability of coincidence, by estimating the total number of visible lines resulting from the observation of a known number of sparks, as well as the velocity of rotation of the moveable disk, we can deduce therefrom, with an ascertained degree of approximation, the duration of the visible spark.

When the apparatus is in operation, only a limited number of coincidences can be seen at one time; so that when the duration of the spark becomes greater and is such that for a velocity of rotation of the disk more than five or six coincidences appear at once, the velocity has to be diminished in order to keep within the limits of that number of coincidences; and from these two quantities the duration of the spark is determined.

It must be remarked that, by the duration of the *visible spark*, must be understood the time which separates the moment at which the spark commences from the instant at which, in consequence of the diminution of its luminous intensity, it ceases to illuminate sufficiently the whole of the lines of the apparatus to give the observer a sensible image, whatever the direction of the discharge or of its subdivisions, while the *total duration* may be greater.

The measurement of the duration of the sparks depending on the number of coincidences seen by the observer, if the degree of illumination of the lines happens to diminish much, it is to be feared that the number of coincidences diminishes equally, in consequence of the weakening of the light corresponding to the end of the discharge. The authors assert that, in the same conditions of production of sparks, the measure of their duration preserves the same value when the velocity of rotation is changed. Now, in this case the illumination of the lines diminishes in proportion as the velocity of rotation is augmented; so that, in the conditions under which they operated, the alteration of luminous

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intensity did not sensibly modify the results of their observations. Still it would be desirable that the authors should be able to explain in what manner the luminous intensity intervenes when comparisons are made between sparks of unequal brightness, especially when the discharges explode between electrodes of various metals, placed at different distances, in gases at divers pressures, and that it should be possible for them, in certain cases, to operate with the same sum of light illuminating the lines of their apparatus.

Since the coincidences of the lines of the fixed and moveable disks depend on the duration of the spark up to a certain limit of illuminous intensity, it must be remarked that their number might be increased in consequence of the phosphorescence of the moveable disk; but mica being one of the solids in which the phenomenon of persistence of this luminous action is the least marked, it follows that no sensible perturbation can arise from the interposition of a moving disk of that substance between a luminous focus and the eye of the observer.

The authors of the memoir have not been able, with the apparatus constructed as it is, to render appreciable the duration of a spark proceeding from an ordinary machine; but they have ascertained that the duration of the discharges from condensers varies with the surface of these, with their disposition, and in proportion to the resistance of the circuit traversed by the electricity; it changes likewise with the exploding-distance, the nature of the knobs of the exciter, and the humidity of the air. In general the duration increases with the surface of the condenser and with the distance of the knobs, and diminishes with the lengthening of the circuit. In these researches, they have given as limits of observed durations 4 millionths of a second and 86 millionths of a second, with a possible error of 1 millionth of a second.

They have been able to represent by empiric formulæ the results obtained in divers series of observations, and have arrived at this consequence—that there is a limit towards which the duration of the spark tends when one augments indefinitely the surface of the condenser and the exploding-distance and diminishes tne resistance of the conducting circuit.

Briefly, MM. Lucas and Cazin have devised an ingenious method of experimenting, which they have studied with care, and which has already led them to some very interesting results in the experiments made with condensers; but it would be important to render this method equally applicable to the investigation of sparks produced by ordinary machines without the intervention of batteries. The Commission, therefore, invite MM. Lucas and Cazin to continue their researches, and have the honour to propose to you to order the insertion of their memoir in the *Recueil des Savants ètrangers.*

The conclusions of this Report were adopted by the Academy.— *Comptès Rendus de l'Acad. des Sciences*, July 8, 1872, pp. 66—69.—*Philosophical Magazine.*

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## ON A NEW GALVANIC PILE, OF ECONOMIC CONSTRUCTION.

By M. GAIFFE.

The high price of galvanic piles and the difficulty of procuring them being often an obstacle to the applications which might be made of them, I essayed the possibility of devising an apparatus that one could make anywhere without the aid of the professional workman, with substances of little value, widely spread in commerce, and possessing the essential quality of constancy in the effects.

The pair which, after some trials, I have adopted, resembles Callaud's in its form, used some years since on telegraphic lines; but its elements are different. It consists of a vessel into which dip two rods—one of lead, the other of zinc. The leaden one descends to the bottom; the zinc is one half shorter. The bottom of the vessel is coated with red oxide of lead (minium); and the exciting liquid is water containing 10 per cent. of chlorhydrate of ammonia.

The electromotive force of this pile is about one third of that of a Bunsen's pair; its internal resistance is slight, and varies little; the chloride of zinc formed does not sensibly alter the conductivity of the exciting liquid; its constancy is great; finally the expense is almost nothing when the circuit is open.—*Comptes Rendus de l'Acad. des Sciences*, July 15th, 1872, p. 120.—*Philosophical Magazine.*

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## ON THE ALLEGHENY SYSTEM OF ELECTRIC TIME SIGNALS.

By Prof. S. P. LANGLEY.

THE necessity of a uniform standard of time for the railways of the United States is one which is growing into importance with the increasing extent of our railway system, and we are, ere long, in this country, to be called on to settle for ourselves a practical problem which has been already solved in England, and which is beginning to make its demand for solution upon the managers of our railroads.

Although the introduction of the plan in this country has been comparatively recent, the number of American observatories which thus distribute time is so considerable that the most partial account of their methods, and the extent of their work, would exceed the limits of such an article as the present. In this, the only arrangements described are those in use at the Allegheny Observatory, with which the writer has become familiar from the responsibility of their initiation and superintendence. It is proper to add that, were he writing a history of the progress of electric time signals in the United States, other observatories which have before employed not dissimilar means, would receive earlier mention, and that his own part in introducing these signals at the Allegheny Observatory has been less the contribution of any novel device than an adaptation of what seemed the best features of plans in use abroad,

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their arrangement in a form adapted to the needs of American railways; and the supervision of their application to the wants of cities and individuals. In doing this a great number of ingenious devices have been examined, and if the system to be described appears to be one of the simplest, it has yet been reached only after much care in setting aside all which would not bear the test of practical trial.

The subject was first specially considered at the Allegheny Observatory some three years since, and a plan was arranged for the managers of the Pennsylvania Central Railroad in 1869. Previously to this, however, at the request of some jewellers of Pittsburg, the time had been transmitted to their stores, at a distance of some miles from the observatory. The system now described has been in use for nearly three years, in furnishing the Pennsylvania Central Railroad with its official standard of time, and by it the time is now sent daily to Philadelphia on the east, as far as Lake Erie on the north, and to Chicago on the west—regulating the clocks on a number of minor roads over whose wires it goes, as well as on those of the principal southern lines connecting the Atlantic with the Mississippi. Thus passing, as it does, over several thousand miles daily, it is believed to be at present one of the most extended systems of time distribution in the world.

The observatory is on the summit of the ascent, on the northern side of the valley of the Ohio, about two miles in a direct line from the offices of the Western Union Telegraph Company in Pittsburg, and rather more from those of the Pennsylvania Central, and Pittsburg, Fort Wayne, and Chicago roads. It is connected with these points by three independent lines of telegraph. One of these runs to the Western Union offices, and thence to the stores of a considerable number of jewellers in Pittsburg. This is called the "jewellers' line." The second, connecting the observatory through the offices mentioned with eastern Pennsylvania and New Jersey railways, and also with Chicago, is known as the "railroad line." The third, consisting of a double wire or "loop," communicating with the city, is employed occasionally for the observatory's own messages, and when (as, for instance, in longitude determinations) it is wished to send sidereal time, without interrupting the regular transmission of signals from the mean time clock. In the transit room, in the western wing of the observatory, are kept the sidereal clock, by Frodsham, of London, and the principal mean time clock, by Howard, of Boston.

On the escape wheel arbour of this, the standard mean time clock, and turning with it once a minute, is a wheel cut with sixty sharp radial teeth, of which those corresponding to the 50th, 51st, 52nd, 53rd, 54th and 59th seconds of the minute have been removed by a file. Near the clock is a "repeater," the circuit through whose coils passes through a local battery, through a second clock in the computing room, and then through the standard clock. Each wire terminates in a delicate spring close by the wheel just mentioned. While the extremities of these springs, which are shod with gold and platinum, rest in

contact, the circuit is unbroken; it is opened by the minutest lifting of one from the other, and this is effected automatically by means of a ruby attached to one of them, and placed within reach of the wheel above mentioned. As each of these teeth passes, the ruby, and with it the spring, is lifted through a minute distance. (Not in practice more than one one hundreth of an inch, and usually much less.) Once a second, therefore, the circuit is opened during a period of probably less than a twentieth of a second, and as the wheel advances a tooth with each vibration of the pendulum, the armature of the repeater is raised each second of the minute until the 49th is completed.

Since the teeth corresponding to the next five seconds have been filed away, during these seconds the jewel is not touched nor the circuit opened. The consequent silence of the "repeater's" beats draws attention to the fact that the end of the minute is approaching, its completion being indicated by the short pause caused by the absence of a tooth at the 59th second.

This action is repeated in every minute of the twenty-four hours without variation. The particular second is thus identified, but one minute is (so far as the action of the standard clock is concerned) not distinguished from another. To do this is the work of the subsidiary clock in the computing room, through which the local wires are led, as has been mentioned. The subsidiary clock (made by Howard, of Boston) may be called for distinction the "journeyman," and its principal office is not to give the time but to interrupt the circuit, which it does on or near the completion of the 58th minute, closing it again about half a minute before the completion of the hour. When the circuit is opened by the journeyman the repeater is silent for a minute and a half; when it is closed, the standard is again heard ticking on the repeater, and the ensuing short pause evidently precedes the first second of the first minute of the hour. The time is thus wholly derived from the standard clock, and is independent of any other; the journeyman having no power to control or in any way re-act upon the primary, and being only able to interrupt the messages it sends, not to falsify them.

The mechanism for effecting the transmission of the time is essentially that already described, but more is needed to insure against possible interruption. This may occur from several causes, prominently from oxidation of the platinum or gold contact surfaces, when the current must be interrupted while they are cleaned, if there be no other clock. To meet this contingency a chronometer of peculiar construction was made for the observatory by Frodsham. It resembles the ordinary marine chronometer in external appearance, but contains in miniature the apparatus for breaking circuit already described, the wheels being cut so as to give the same signal of the approaching end of the minute as the standard clock. The peculiarity consists less in this, however, than in a device by means of which it can be caused to gain or lose any fractional part of a second, or any number of seconds, without being stopped, and without any disturbance of its normal rate, except while the

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change is being effected. This chronometer is to replace the prime clock in the circuit, during any temporary stoppage of the latter for repair or adjustment.

The mechanism which has just been described acts in connection with the local circuits of the observatory—one battery being employed for the sidereal clock and chronograph, and another for the mean time standard. Any interruption of the main external circuits is shown at once by the action of a galvanometer in each, which makes an audible and visible signal when the circuit is opened. The accessory apparatus, such as batteries, relays, switch-boards, and so forth, which are used in every telegraph office, it will be superfluous to describe here in detail, but before following the operation of the electric current, outside the observatory, it will be well to speak of the method which has been adopted as likely to ensure most accuracy in the time keepers which control it.

The transit instrument in the western wing is of four inches aperture, and with it and the chronograph, observations for time are made on every fair night of the year except on Sunday, when, if complete determinations have been made on the preceding night, none are taken. The instrument is of sufficient power to follow the principal nautical almanac stars in the day, and these are used (or more rarely the sun) when the weather permits if the usual night observations have been missed. From three to six stars are customarily taken, the azimuthal error of the instrument being found from the observations of each night, after the other corrections are applied, and the results determined from the chronograph and the sidereal clock. The mean error in the resulting determination of the sidereal clock correction is from three to four hundredths of a second, but it cannot be assumed that that of the mean time standard is known within these limits, except at the time that the observations are freshly made.

It may be desirable to point out where the system pursued here differs from that in which a few signals are sent at stated hours, as at Greenwich. In the case of the time ball, for instance, dropped daily by a clock at Greenwich, mean noon, it is customary to compare the mean time clock which drops it with the sidereal time a few minutes before twelve. If it (the operating clock) be slow it is caused to gain, and if fast, caused to lose an amount needed to bring it to coincidence before the automatic action gives the signal.

The time of this signal is nominally exact, but in fact involves the variations in rate of the standard clock or clocks which are treated in the comparison as having their errors absolutely known. It is by no means meant to criticise this procedure, but to point out that an error must exist where the rates of the clocks are treated as constant intervals between observation, no less real accuracy is reached in the method employed here, in which (as the signals are being constantly sent) the signeling clock has no less nominal error at noon (for instance) than at any other hour.

When the sidereal clock has entered its beats upon the chronograph, during

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the time of observation, the record is not interrupted until, the mean time standard having been put into the same circuit, both clocks have automatically entered their time on the sheet together, and the break-circuit chronometer has done so also. The sheet being removed, and the breaks of the transit observer measured, the comparison of the various clocks with electric attachments are taken by measurement on the same sheet, and the others compared with the sidereal clock by noting coincidence of beats by ear. The resulting errors of all are then determined, reduced to a common epoch, and entered in a permanent record kept for the purpose in the following form:

($\Delta$T, $\delta t$, being the usual symbols for the respective corrections of error and date):

Aug. 10, 1872. Time stars { $\eta$ *Herculis*, $\alpha$ *Camelop.*, $\varkappa$ *Ophinchi*, $\delta$ *Herculis*, } A. E. F., observer.

| At mean 9$^h$ | $\Delta$T. | $\delta t$. |
|---|---|---|
| Sidereal clock, | 7$^s$·32 | +1$^s$·18 |
| Break-circuit chron. | +2$^m$·22$^s$·18 | +3$^s$·30 |
| Cron. 3242, | + 50$^s$·05 | +3$^s$·11 |
| Mean time standard | — 00$^s$·27 | +0·46 |

The mean time clock is here 0 27 fast by actual observation, but when the next comparison is made the following morning (at 21 hours) its error can usually be obtained only by comparison with another clock. If it be compared with each of the other clocks in turn, each, owing to the variations of its rate during the night, will probably give a slightly different result—but supposing all the time keepers equally reliable, the probable error will be less, in taking the mean of the four, than by any single one.

The above corrections for error and rate having been applied to the sidereal clock, a comparison is taken with it in the morning, and the resulting time of the mean time clock noted, on the assumption that the sidereal clock is an exact standard. The same comparison is made with each, after the respective corrections and rates have been applied, each being successively treated as an independent standard.

The results will then be entered in this form:

1872. August 10$^d$ 21$^h$

Error of mean time standand, — 0$^s$·19 (by sidereal clock).
" " " " 0$^s$·05 " break-cir. chron.
" " " " 0$^s$·11 " chron. 3242.
" " " " 0$^s$·04 " its own rate.

The mean or "adopted" error of the mean time standard is then—

$$\frac{-0^s\cdot 17}{4} = -0^s\cdot 04$$

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In the absence of any more absolute criterion the time of the standard in this instance is assumed to be kept four one-hundredths of a second fast, and this value is adopted and treated as though it represented an error determined by direct comparison with the stars. The clock will be compared again at 9 in the evening, and when this "adopted error" exceeds 0·25 such a change is made in the pendulum as will correct the error—not abruptly, but gradually during the ensuing twelve hours.

It is of course impracticable to stop the clock and raise or lower the adjusting screw twice daily for such minute corrections, and many ingenious devices have been proposed for effecting the change without stopping the instrument. One of these, as applied to a chronometer, has already been referred to; another (employed at Greenwich) involves the use of a small bar magnet permanently attached to the pendulum, and swinging with it; and still another the changing tension of a long spiral spring, which connects the "bob" with the clock case.

After considering many such plans, that adopted was the old one, familiar to most observers, of placing weights on the top of the bob of the pendulum, and then adjusting the bob by the screw till it runs with them approximately, after which a small increment or decrement of the weights will keep the clock under control. This plan has the advantage of employing as an agent gravity, whose effects can be reckoned on with more certainty than electricity or the tension of a spring. In common with the others it has however, as commonly employed, the defect that when changes are made daily or oftener the *rate* of the clock cannot be ascertained, and that reliance must be placed at the times of comparison only on other clocks whose rates are undisturbed. The writer has, therefore, found it advantageous to use these weights quantitatively, by making them of a size such as to cause a gain of one second a day; 01 an hour, etc. Weights representing three or four seconds are kept on the top of the bob, so that their removal will retard the clock, if desired, to that amount.

A record is kept in which the comparisons in the tabular form above given are entered twice daily, the amount of the weights and the consequent rate which the clock so controlled would have had with an undisturbed pendulum being noted likewise.

The barometer and clock case thermometer are also read twice daily, for the purpose of laying down curves representing the separate effects of temperature and pressure, Another curve, whose ordinates represent the algebraic sum of the corresponding ordinates of the first two, shows the combined results of both, for comparison with still another representing the clock rates. These are chiefly useful in the occasionally long intervals of cloudy weather which occur in winter. At such times the clock rates are obtained by interpolation from the curves, and "weighted" according to the degree of dependence on each clock before making up the final or "adopted error" of the standard. When observations are obtained daily, however, such precaution is needless.

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Those who are aware of the number of patented devices for controlling distant clocks by electricity, may perhaps feel surprised that so little mention has here been made of their use.

Some of these are of extreme ingenuity and much promise, and the English patents covering such points are alone to be reckoned by scores. Plans have been submitted to the writer by which the clocks along any number of miles of road could be set right, and brought to uniform time in a few seconds, by the operator at the observatory, and these plans appear feasible. The arrangements adopted here, as the reader will observe, do not greatly differ from these employed in telegraphic determinations of longitude, and in fact a prolonged examination of very many ingenious devices for directly controlling distant clocks led the writer to set them all aside, and to employ methods not differing in principle from those in use already, for purely scientific ends, in most American observatories.

Of the very numerous plans for controlling distant clocks that of Jones (now well known) appears to be the best, but even this is not quite reliable where the circuit is a long one. The clocks described have subsidiary apparatus enabling them to send controlling currents on the Jones plan, but thus far its use has been confined to the observatory, has therefore been hitherto done by the sending of signals, through which distant clocks may be *regulated*, but without employing means for their *control*, and though this is done over a very extended field, a brief description of it, under the three divisions into which it naturally falls, will suffice:

1st. The supply of time to watchmakers and jewelers. The "jewelers wire" passes through the Western Union telegraph offices and the stores of the principal jewelers of Pittsburg. Beside each "regulator" is a telegraphic sounder, on which the observatory time is heard constantly ticking, and by which almost, if not quite all the clocks and watches of the city are thus at second-hand regulated. There is, in this uniform and recognized standard, everywhere accessible, a convenience to watchmakers, of course, but still more to the public, as the discrepancies between clocks, public or private, which cause so many lost minutes in the day to each person in a city, that their aggregate represents a large draft upon the time of the business public, disappear.

Applications have been received from watchmakers in neighbouring cities, and at a considerable distance from Pittsburg, for this telegraphic supply of time, which it has not always been possible to accommodate, but which have been welcome, as showing a public appreciation of the utility of the work.

2nd. The supply of time to railroads. The watchmakers and jewelers are in permanent telegraphic connection with the observatory by a wire which is devoted to their use—but distant cities, such as Chicago or Philadelphia, can be reached only by the wires of the telegraph or railroad companies which are too valuable to be exclusively employed for this purpose.

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The method used on the Pennsylvania Central, and Pittsburg, Fort Wayne and Chicago roads, will sufficiently illustrate the system as applied to railways.

A special wire connects the observatory with the office in which the wires owned by these roads unite. In this office is a small bell, which is struck lightly every second, in the manner described, and except for the pauses to designate the minute and hour, continues to sound unintermittingly, affording to the conductors and other employés specially concerned in the time a means of ready comparison, even without entering the building.

At 9 and at 4, Altoona time (ten minutes fast of Pittsburg), the Pittsburg operator in charge connects the main eastern wire to Philadelphia, 354 miles distant, with the observatory, and for the ensuing five minutes the beats of the Howard mean-time standard are automatically repeated on similar bells, or on the customary "sounders" in Philadelphia, and in every telegraph office through which the road wire passes—all station clocks and conductors' watches being compared with it as the official standard. After five minutes the clock is "switched" by the Pittsburg operator out of the main line wire, which is returned to its ordinary use.

A similar set of signals, lasting for five minutes, is sent at 9 and 4 of Columbus time (thirteen minutes slow of Pittsburg time) to all stations as far west as Chicago, inclusive, in the main western line (of 468 miles in length). At Philadelphia the time is repeated to New York, at Harrisburg to Erie (333 miles), etc. As it is thus sent not only over the main lines from New York to Chicago (nearly a thousand miles), but over a number of subsidiary or branch roads too great for enumeration here, and which form in the aggregate a much larger number of miles than the main trunk, it will be observed that a considerable fraction of the railway system of the whole country is prepared for using a single unit of time; as, though the names of "Philadelphia time," "Altoona" or "Columbus time" are not yet abolished over that part of our railway system referred to, every railroad clock and watch, and the movement of every train is regulated from a single standard—that of the clock in the observatory.

The advantages of this uniform and wide distribution of exact time in facilitating the transportation of the country, and in enhancing the safety of life and of merchandise in transit between the Western and the Atlantic cities, seem to be sufficiently evident. The fact that the system described in this article has obtained the extension it has, within three years from its commencement, will, it may be hoped, justify the belief that its use has proved not only valuable to railways but an added security to the safety of the public.

3rd. Supply of time to cities. At present arrangements are in progress for regulating the principal public clock of Pittsburg (the turret clock of the City Hall about two miles from the observatory), which it is intended shall strike every third hour on the bells of the fire alarm, and probably also in the

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various police stations. As the mechanism for doing this is still in course of construction, and may yet be modified in trial, it would be premature to speak of it, especially as its success has not yet been proven in practice here. The city clock will automatically report its own time to the observatory by a special wire, and it is probable that in controlling its rate from the observatory the "Jones" system will be used.

The necessity of a uniform standard of time over the whole country, which was alluded to in the outset as one of growing importance, has not been further directly touched upon in this article, which is yet as a whole devoted to describing the means of meeting it. The evident tendency, in thus sending the time from one standard over so large an extent of territory, is to diminish the number of local times, and so prepare the way for a future system, in which, at least between the Atlantic and the Mississippi, they shall disappear altogether.

A step in this direction has been contemplated by the managers of the roads uniting New York, Philadelphia, Pittsburg and Chicago, who have intended to use the time of the meridian of Pittsburg between the two extreme points mentioned, running all trains from New York to Chicago by this time alone, in place of using successively the local times of Philadelphia, Altoona and Columbus, as at present. Such a change would have already taken place during the last summer, except for an unexpected cause of delay, on whose removal it will be effected.

The labors of this and of other American observatories are tending to the same important end—that of the ultimate adoption of some single time for the country east of the Mississippi, by which not only the railroads but cities and the public generally will regulate themselves. What point shall be chosen is of less importance than that some *one* should be used and universally.

The subject is one which has hitherto attracted little public attention, but it does not seem unsafe to make the assertion that the causes which have almost insensibly effected such a revolution in England, will in a few years more bring it about here.

Allegheny Observatory, Allegheny, Penn.,
Sept. 22, 1872,

*American Journal of Science and Arts.*

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## TELEGRAPHIC PROGRESS.

The telegraph line has been completed between Mazatlan and Durango in Mexico. The former city hopes to be in telegraphic communication with the capital at an early day. Another line is being constructed between Campache and Mination.

A company of Mexican capitalists has been formed for the purpose of constructing a national telegraph line between the City of Mexico and the northern frontier, to follow the line of the proposed interoceanic railway, and pass through all the principal towns and cities.

The Scrabster correspondent of the *Scotchman* has ascertained that the defects in the Pentland Firth Cable are much greater than were at first supposed, and have necessitated the lifting of the entire cable from Caithness to Orkney, a distance of about fourteen miles. At various places the outer wire coating was found to be cut through, at others the twinings of the wire were unlaid, and the cable was otherwise much chafed. Some time must elapse before the cable will be ready for re-laying, as wherever any defects appear it will have to be cut, tested, and spliced anew. From the very exposed route in which the cable was laid, it is doubtful whether it will remain workable for any great length of time in the position in which it has hitherto lain, the ground being composed of sharp rocks for the greater part of the way, especially at the Orkney side, and the current at spring tides in the Firth very strong, running at the rate of eleven knots an hour. To resist the friction arising from such a current would require a cable weighing about twenty tons to the mile whereas the cable now about to be relaid weighs only about five tons to the mile. It is considered that if the route from Holborn Head, in Caithness, to Stromness, in Orkney, by Hoy Sound, were chosen, the current would not be felt nearly so much, and the ground, not being so rocky, would be better adapted for a cable route. As the Government now intend to take the management of it into their own hands, it is expected that in the future more satisfactory arrangements will be made.

The late spell of warm weather, in its action upon the ice in the Hudson and Delaware rivers and the streams feeding them, caused considerable damage and trouble to telegraph wires and cables. Closely following upon the rise of the Delaware, which, at Trenton submerged all of the wires crossing upon the bridge and inflicted other damage to telegraph property, we learn that the outgoing ice at Albany, N. Y., caught five cables belonging to the Western Union Telegraph Company, each containing seven wires. pulling them out from the cable house on one shore, but fortunately they remained fast at the other, and can easily be relaid when the state of the river renders it practicable. Connection was at once made by stringing wires across the bridge, and but little or no delay occurred to business. At Stockport, lower down the river, the bridge

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was carried away, and with it went six wires, all the wire upon that route. The cable crossing Catskill Creek was also torn away. They have since all been repaired.

All efforts to recover the Aspinwall and Jamaica cable have for the present it would seem, been suspended, and are not likely to be resumed for some months to come. In another column of to-day's issue we give our Jamaica correspondent's version of the action of the Cable Manufacturing Company in regard to the lost cable. Since it was put in type we have been favoured with an extract of a private letter from Sir Charles Bright on the same subject, received by last mail. From it we learn that the weather was so unfavourable when he last attempted to search for the cable, that he was able to put his grappling down but once, and that only for a few hours. He recovered the cable in six hundred fathoms, but the strain was so great the grappling gear broke. As the weather would not permit of successful grappling at this season, Sir Charles concluded to suspend operations for the present and send the steamship International to England for repairs, which are necessary. The steamship Dacia, will come out in her stead to look after the Havana and Key West cable, and after repairing it she will come down and search for the Jamaica and Aspinwall cable and put it in order. Sir Charles Bright expects to come out again in the spring, when the weather is more favorable. He says he can recover the cable at any time when the weather permits. Sir Charles Bright has recalled his agents from the Isthmus, and has given instructions to the managers of the railroad company's telegraph to receive no money or messages on his account. All despatches for the West India cable are in future to be delivered to the agent of that company on the Isthmus, or sent to the company's own office in Kingston, Jamaica.—*Panama Herald, Jan.* 16.

The results of some recent researches on the electrical resistance of various metals have been published by M. Benoit, who gives the following table of the specific resistances, at Zero Centigrade, of 1 metre in length by 1 square millimetre in section, measured by two different systems; namely, in *Ohms* and in *Siemen's Units*—and the conductivities reduced to a ratio in reference to that of silver as a standard.

| | Ohms. | Siemen's Units. | Silver Unity. |
|---|---|---|---|
| Silver—pure, annealed ... | 0·0154 | 0·0161 | 100·00 |
| Copper—annealed ... ... | 0·0171 | 0·0179 | 90·00 |
| Silver—$(\frac{75}{100})$ annealed ... | 0·0193 | 0·0201 | 80·00 |
| Gold—pure, annealed ... | 0·0217 | 0·0227 | 71·00 |
| Aluminium—annealed ... | 0·0309 | 0·0324 | 49·70 |
| Magnesium—hammered ... | 0·04 3 | 0·0443 | 36·40 |
| Zinc—pure, annealed at 350° C | 0·0565 | 0·0591 | 27·50 |
| Zinc—pure, hammered ... | 0·0594 | 0·0621 | 25·90 |
| Cadmium—pure, hammered | 0·0685 | 0·0716 | 22·50 |
| Brass—annealed ... ... | 0·0691 | 0·0723 | 22·30 |
| Steel—annealed ... ... | 0·1099 | 0·1149 | 14·00 |
| Tin—pure .. ... ... | 0·1161 | 0·1214 | 13·30 |

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| | Ohms. | Siemen's Units. | Silver Unity. |
|---|---|---|---|
| Aluminium Bronze—annealed | 0·1189 | 0·1243 | 13 00 |
| Iron—annealed ... ... | 0·1216 | 0·1272 | 12·70 |
| Palladium—annealed ... | 0·1384 | 0·1447 | 11·10 |
| Platinum—annealed... ... | 0·1575 | 0·1647 | 9·77 |
| Thallium ... ... ... | 0·1831 | 0·1914 | 8·41 |
| Lead—pure ... ... ... | 0·1985 | 0·2075 | 7·76 |
| Maillechort—annealed ... | 0·2654 | 0 2775 | 5·80 |
| Mercury—pure ... ... | 0·9564 | 1·0000 | 1·61 |

These results were found to vary according to temperature.

The report of the Telegraph Construction and Maintenance Company (Limited), presented on the 11th of March last, shows an available total of £57,535, and recommends a dividend of £1 4s. per share, or 10 per cent., making, with the amount already paid, a total dividend of 15 per cent., and leaving £12,715 to be carried forward. It appears that the cable for the duplicate French Atlantic line from Land's End to New York, *via* Halifax, has been manufactured, and that 2,567 miles are now embarked on board the "Great Eastern;" the remainder is in course of shipment, and the whole will be submerged during the summer of this year. Also that the Directors, in 1872, succeeded in obtaining exclusive concessions for establishing a complete system of submarine telegraph communication between Portugal and Brazil. Last month a company was formed to carry out these concessions, the necessary capital was subscribed, and a contract entered into with this company for manufacturing a total length of 3,866 miles of cable, and laying the same during 1873 and 1874 between Lisbon and Pernambuco *via* Madeira and the Cpae de Verd Islands.

The River Plate and Brazil Telegraph Company (whose prospectus has just been issued) have recently obtained exclusive privilege for forty years from the Brazilian Government for a submarine cable to connect Rio de Janeiro with Uruguay, where the line will join that of the Monte Videan and Brazilian Telegraph Company, and thus establish through communication with the principal cities of the River Plate, whence, by the Transandine land line, there is already direct telegraphic intercourse with the Pacific at Valparaiso. The cable is in course of manufacture by Messrs. Siemens, and is to be laid by the 15th of August next, and within about ten or eleven months of that date the completion of the line of the Brazilian Submarine Company will place the whole system in communication with Europe.

The report of the India Rubber, Gutta Percha, and Telegraph Works Company (Limited) has been issued. In addition to completing contracts for Her Majesty's Government, the company has manufactured and delivered a cable during the year for the River Plate Company, and has made and laid a cable from England to Spain for the Direct Spanish Telegraph Company. The company is now engaged in manufacturing the third cable for the International Ocean Telegraph Company of New York, with which the "Dacia" will shortly proceed to Havannah for the purpose of laying. It is added that

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the position of the undertaking with regard to the West India and Panama and Panama and South Pacific Companies has not altered, "although a committee of your directors met the committees respectively appointed by these companies with an earnest desire to bring about a fair and reasonable settlement of the questions at issue."

THE cable of the Great Northern Telegraph Company between Hong Kong and Shanghai has been restored, and the connection with Amoy has simultaneously been established.

IN 1867 there were in New Zealand 1,447 miles of wire, and the amount received for messages was £14,295. In 1870 there were 3,159 miles of wire, through which 181,860 private and 56,335 Government messages were sent, the total charge for which was £27,442. Since then, the progress has been very considerable.

THE Queensland authorities propose to devote £60,000 to telegraph extension purposes. The wire is to be manufactured in England.

THE New York, Newfoundland, and London Telegraph Company have decided upon abandoning the greater portion of their land line, which terminates at Cape Ray, and on sending the whole of their messages through the submarine cable recently laid from Placentia *via* St. Pierre, to Sydney, in Cape Breton.

THE telegraphic lines of the Republic of Salvador, C.A., are all reported in good working order.

IN Nicaragua, C. A., Don Adolfo Escobar has been named Director-General of Telegraphs.

THE direct Spanish Telegraph Company have announced that direct telegraphic communication with Spain has been established by the laying of a submarine cable between Bilbao, in Spain, and the Lizard, in Cornwall, and that the line has been opened for public traffic.

A DECREE has been issued granting a concession to Lascarte for laying a telegraph cable between Spain and Cuba. Offers have been received by the Spanish Government from British Companies, for the purchase, maintenance, and management of the telegraph lines.

A CONTRACT has been signed by Messrs. Siemens Brothers, to lay a submarine cable (under exclusive privilege for forty years) between Rio de Janeiro and the cities of the River Plate (Montevideo, in Uruguay, and Buenos Ayres in the Argentine Republic). This cable is for the Platino Braziliera Telegraph Company, represented in London by Mr. A. Ricke. It is to be laid within six months, the capital having been entirely subscribed in South America.

THE tender of Messrs. Siemens Brothers, telegraphic contractors, has been accepted by the Government for the construction of a line from Fort Beaufort to Colesberg.

NATIVE merchants have petitioned the Japanese Government for permission to construct railroads and telegraph lines. The petitions were granted. The work is to be done under the supervision of the Public Works' Department.

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Further steps have recently been taken for the complete amalgamation of the Anglo-American, the French Atlantic, and the Newfoundland Companies, touching which a recent prospectus recites the various rights and concessions of the companies, among which is the right to select, free of charge, 100 square miles of land in Newfoundland. The revenues of the Anglo-American Company amount to a payable rate of 12¾ per cent.

The Trans-Andine Telegraph has reached Jujui, thus placing the northern portion of the Argentine Republic in communication with Chili.

The Government of Honduras is endeavoring to have established a telegraphic line between Honduras and Salvador.

In consequence of the success of the trials, made on the line of telegraph from Berlin to Dresden, of a new kind of metallic posts, which are found to be so much more stable and durable as to compensate largely, in maintainance for the greater prime cost, the Government has it in contemplation to provide all the lines with metallic telegraph posts.

The Eastern Telegraph Company announce that the average actual time in the transmission of messages from Bombay, during the month of November, was one hour and thirty-seven minutes, which, by comparison with the return for October, is an improvement in speed of twenty-two minutes. An improvement of 1½ hours has also occurred in the average speed from China.

The Government of Spain has signed a concession for a telegraph cable from Cadiz to Cuba, by way of the Canaries and Teneriffe.

Resolutions have been passed by the Boards of the British Indian Extension, China Submarine, and the British Australian Telegraph Companies, agreeing, subject to the assent of the shareholders, to amalgamate their several undertakings on the basis of an allotment of shares in the amalgamated company as follows:—British Indian Extension, £15 per share; China Submarine, £11 per share; British Australian, £11 per share.

The *Great Eastern*, lying in the Medway, has received on board the whole of the deep-sea section of the new Atlantic cable. Already there have been four cables laid, one of them only being in operation at this moment. The first, laid and broken in 1865, picked up and completed in 1866; and the second, laid in 1866, from Valentia, in Kerry, to Newfoundland, belong to the Atlantic Telegraph Company and to the Anglo-American Telegraph Company. The third, laid in 1868, from Brest to New York, belongs to the Société du Cable Transatlantique Francais. The new cable is the property of the same company, and it is intended to lay it in May and June, the ship being appointed to leave her moorings on the 20th of May. It is remarkable that the wires of this new cable, which is nominally the property of a French company, will both leave and enter British soil. The point of departure is a place called Germoe, on the north side of Mount's Bay, Cornwall and the cable will be landed at Freshwater Cove, in Halifax harbour, on a piece of land in the occupation of the War Office, by which leave to use the cove has been granted. There will

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then be laid a branch cable from Freshwater Cove to Hog Island, near the end of Long Island, and only fifteen miles from Sandy Hook, nor much more from Brooklyn. The new cable differs somewhat from any of those hitherto laid, either to America or elsewhere. There are seven No. 18-gauge copper wires, twisted in a spiral, and weighing 300 lb. per nautical mile, and these are covered with four coats of gutta percha, with thin layers of Chatterton's compound, this amounting to 400lb. per knot. The diameter of each wire is 0·048 inch; of the strand, 0·146 inch; and of the wire and gutta percha and compound; 0·464 inch. This core is served with hemp, and the hemp is again protected by ten wires drawn from homogeneous iron, each wire being sewed with five yarns of Manilla hemp laid on spirally, with a tarry compound to preserve it. The cable weighs nearly two cwt. per knot more than the previous cables; but it is even stronger in proportion, and is calculated to last at least twice as long under the same conditions.

It is stated that the 1865 cable of the Anglo-American Company is broken 468 miles from Valentia (Ireland). The Admiralty chart shows 1,875 fathoms of water at that spot. It has been suggested in consequence of this accident that the new cable of the French Atlantic Company should adopt the shortest sea route, and, instead of being laid to New York *via* Halifax direct, should be divided into two cables, both to be laid forthwith from Ireland to Newfoundland. The length of a cable to Newfoundland is about 1,900 miles, while the length ready for shipment to establish the direct route, *via* Halifax, is over 3,600.

The French Atlantic Cable has just met with an interruption; the fault is stated to be 200 miles from Brest in 100 fathoms water, and it is hoped to be repaired very shortly. In the mean time the Directors have announced an increase of tariff to six shillings per word, as only one cable is now available for traffic.

Mr. C. H. Summers communicates the following account of the electrical phenomenon which accompanied the great storm of January 7th and 8th:—

"The disturbances were first noticed in the wires in Central Iowa. The lines leading West were rendered useless for the transmission of messages, owing to an incessant discharge of electricity, increasing in intensity until it would leap from one strap of the switch-board to another, across the intervening space, and then in a luminous stream to the ground-plate of the lightning-arrester. Another singular fact observed was that, on some routes where a number of wires occupied the same poles, one wire alone was highly charged, and so affected that to work it was an impossibility, while all the others were entirely free from any external influence. In some cases the wire occupying the top of the pole would apparently receive the whole charge; in others the bottom wire would be affected, and in a few cases the charge was equally distributed among all the wires. In the Chicago office the effect was similar to that observed in Iowa, and every observation confirmed the opinion that the

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centre line of the storm was due east from Des Moines, Iowa, to Detroit, Michigan; narrowing in its limits north and south as it approached the latter place, where it arrived on the evening of the 8th ult., and rapidly subsided, A high wind, varying from twenty-five to twenty-eight miles per hour, accompanied the storm."

April 23rd, 1873. G. E. PREECE.

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# Obituary.

## SIR DONALD M'LEOD, K.S.I.

We regret to have to announce the death of a member, whose connection with the Society was of a very short duration.

The late Sir Donald M'Leod, who was unfortunately killed by an accident in getting into a Metropolitan Railway train, at the Gloucester-road Station, on the evening of the 28th November last, was one of the most experienced and highly esteemed Indian statesmen of the day. He was the son of the late General M'Leod, of the Bengal Engineers, and grandson of a Scottish laird, Donald M'Leod, of Ross-shire. He was born in 1810, in India, and was sent home for education, first at the High School, Edinburgh, subsequently in private institutions in England, until 1826, when he obtained an appointment in the Indian civil service, and proceeded to Haileybury, where he was a contemporary of the late Sir G. Edmonstone, formerly Lieutenant-Governor of the North West Provinces, Sir J. P. Grant, now Governor of Jamaica, and Lord Lawrence. At Haileybury he took high honours in the native languages, mathematics, and drawing. During the first three years of his career in India he was employed at Monghyr, in the provinces of Bengal; then for twelve years in the Saugor and Nerbudda territories. For a short time he assisted the late Colonel Sleeman in the suppression of murders by Thugs and Dacoits; and for six years filled the office of Magistrate of Benares. He gained a high reputation by the happy influence he exercised over all classes of the people and the manner in which he secured their co-operation in matters of local improvement and the repression of crime. His success as Magistrate of Benares led to his promotion, in 1849, to the important post of Commissioner of the territory then recently acquired from the Sikhs, and known as the Trans-Sutlej States. There his rare powers of conciliation had ample scope in smoothing the difficulties and allaying the animosities incidental to the successive domination of Sikhs over Rajpoots and Englishmen over Sikhs. In 1854 he became Financial Commissioner of the Punjaub, and during the crisis of 1857 was, with Sir Robert

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Montgomery, one of the trusted councillors of Sir John Lawrence, who has borne testimony to the value of his services and his serene and resolute bearing in that trying time. In 1855 he was, on the recommendation of Sir John Lawrence, appointed Lieutenant-Governor of the Punjaub, and shortly afterwards received the honour of Knight Commander of the Star of India, the Companionship of the Bath having been granted him in recognition of his services in 1857. After holding office five years and a half as Lieutenant-Governor, he handed over the government to the late Sir Henry Durand, and returned to England from a service of upwards of forty years, during the whole of which period he only visited England once.

Throughout his long career of Indian service, whether Magistrate of a district, or Commissioner of a division, or Lieutenant-Governor of a province, the distinguishing characteristic of Sir Donald M'Leod was a warm sympathy with the people, and an earnest desire so to regulate the system of administration as to be in harmony with their feelings, and to win them over by enlisting their confidence.

Sir Donald M'Leod was elected a member of the Society of Telegraph Engineers, on the evening of Wednesday, the 27th November last, and it is to be greatly regretted that the Society so soon lost a member who would undoubtedly have contributed greatly to its success.

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## ERRATA.

Page 357, line 9, for "protecting," *read* "protected."

Page 355, line 29, for "Liverpool 'Express' institutions," *read* "Liverpool 'Express' instruments;" ditto, lines 2 and 4 from bottom, *read* "boards" instead of "bands."

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THE SOCIETY OF TELEGRAPH ENGINEERS is established for the general advancement of Electrical and Telegraphic Science, and more particularly for facilitating the exchange of information and ideas among its Members.

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| Radcliffe, Arthur | 101, New Street, Birmingham. |
| Ramsay, John, Lieut. R.N. | Post Office Telegraph, London Bridge, S.E. |
| Reid, Frank | Postal Telegraphs, Newcastle-on-Tyne |
| Richardson, H. | Postal Telegraphs, Douglas, Isle of Man. |
| Risch, Gustav | 9, Armstrong Terrace, New Charlton, S.E. |
| Ritso, F. C. G. | 7, Lothbury, E.C. |
| Robertson, J. | Postal Telegraphs, Bristol. |
| Rolls, Edward T. | L. & S. W. Railway, Southampton. |
| Russell, Frank | 2, Talbot Court, Gracechurch St. |
| Saunders, H. | British Indian Submarine Telegraph Company, 66, Old Broad Street. |
| Sax, J. | 103, Great Russell Street, W.C. |
| Schramm, Otto | 3, Gt. George Street, Westminster, S.W. |
| Shaw, John | Postal Telegraphs, Bolton. |
| Siemens, Alexander | 3, Gt. George Street, Westminster, S.W. |
| Sivewright, James | Postal Telegraphs, Southampton. |
| Smith, Toulmin | 3, Gt. George Street, Westminster, S.W. |
| Spagnoletti, Hylton | 4, Circus Street, Marylebone, W. |
| Stevenson, Ed. Alf. | Telegraph Construction and Maintenance Company, Enderby's Wharf, East Greenwich, S.E. |
| Stokes, John Scott | Postal Telegraphs, Southampton. |
| Symington, Robert Stevenson | Postal Telegraphs, Glasgow. |
| Taylor, William Grigor | Telegraph Construction Company, Morden Wharf, East Greenwich. |
| Theiler, M. | 156, Barnsbury Road, N. |
| Tolmé, Julian H. | 1, Victoria Street, Westminster, S.W. |

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| | |
|---|---|
| Treuenfeld, Von, Fischer | 277, Vauxhall Bridge Road, S.W. |
| Tubb, Albert | Postal Telegraphs, Southampton. |
| Walton, John | Postal Telegraphs, Cardiff. |
| Watkins, Lieut. R.E. | Aldershot. |
| Watson, C., Lieut. R.E. | Chatham. |
| Werdermann, E. H. | 4, Princes Street, Stamford Street, Southwark, S E. |
| Willmot, Joseph | Postal Telegraphs, General Post Office. |
| Winter, Charles | Postal Telegraphs, Guernsey. |
| Woollen, C.H. | Postal Telegraphs, Exeter. |

## STUDENTS.

| | |
|---|---|
| Graham, William John | Henley's Works, North Woolwich, E. |
| Palliser, Edward | 2, Westminster Chambers, S.W. |

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# LIST OF MEMBERS

OF

# THE SOCIETY

OF

# TELEGRAPH ENGINEERS.

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**ESTABLISHED 1871.**

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CORRECTED TO

1ST JANUARY, 1873.

LONDON:
JOHN KING & CO., 35, OLD JEWRY, AND QUEEN STREET PRINTING WORKS, E C.

1873.

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# NOTICE.

It is particularly requested that any change of Residence or Address may be communicated at once to the Secretary.

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THE

# Society of Telegraph Engineers

ESTABLISHED 1871

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Frederick C. Danvers (India Office).

**TREASURER.**

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**HON. SECRETARY.**

Major Frank Bolton.

**HON. SOLICITORS.**

Messrs. Wilson, Bristows & Carpmael.

**SECRETARY.**

Geo. E. Preece,
31, Bedford Street, Covent Garden, W.C.

**OFFICE.**

5, Westminster Chambers, London, S.W.

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# The Society of Telegraph Engineers.

THE SOCIETY OF TELEGRAPH ENGINEERS is established for the general advancement of Electrical and Telegraphic Science, and more particularly for facilitating the exchange of information and ideas among its Members.

Any person desirous of being admitted into the Institution must be proposed and recommended according to a form, in which the name, usual residence, and qualifications of the Candidate (comprising a sketch, with dates, of his professional career, enumerating the works on which he has been engaged, and the positions he has occupied), must be distinctly specified. This form must be signed by at least four Members, certifying a personal knowledge of the Candidate.

The proposal of any Foreigner, who may be desirous of joining the Institution, must be signed by at least one Member, certifying personal knowledge of the Candidate and a full conviction of his qualifications.

The Society consists of Members, Foreign Members, Associates, Students, and Honorary Members.

MEMBERS.—Every Member shall have been previously elected as an Associate of the Society, and shall come within one of the following conditions:—

(A.) He shall have been regularly educated as a Telegraph Engineer, according to the usual routine of pupilage, and have had subsequent employment for at least five years in responsible situations.

(B.) Or he shall have practised on his own account in the profession of a Telegraph Engineer for at least two years, and have acquired a degree of eminence in the same.

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(c.) Or he shall be so intimately associated with the science of Electricity, or the progress of Telegraphy that the Council consider his admission to Membership would conduce to the interests of the Society.

ASSOCIATES shall be of more than twenty-one years of age, and this class shall include persons whose pursuits constitute branches of Electrical Engineering, who are not necessarily Telegraph Engineers by profession, but who are, by their connection with Science, qualified to concur with Telegraph Engineers in the advancement of professional knowledge.

STUDENTS shall be persons not under eighteen and not over twenty-one years of age, who are serving pupilage to a Telegraph Engineer, or who are studying Natural Science, and are duly recommended by a Member.

HONORARY MEMBERS shall be either distinguished individuals who from their position are enabled to render assistance in the prosecution of Telegraphic enterprises, or persons eminent for science and experience in pursuits connected with the profession of Telegraphy, but who are not engaged in the practice of that profession.

FOREIGN MEMBERS are also admitted, paying a subscription of £1 a year.

Every Member shall contribute the sum of Two Guineas, every Associate the sum of one Guinea, every Foreign Member £1, and every Student Half a Guinea, annually, to the Society.

Any Member or Associate absent from the United Kingdom nine months out of the year, shall contribute the sum of £1 per annum.

Honorary Members shall not be required to pay any contributions.

The annual contributions shall be payable in advance on the 1st of January in each year.

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Any Member may compound for his annual subscription by the payment, in one sum, of Twenty-five Guineas. All such compositions shall be invested in the names of three trustees, and the interest alone shall be appropriated to the current expenditure of the Society, at the direction of the Council.

The Meetings of the Society are held by the kind permission of the Council of the Institution of Civil Engineers, at their Institute, 25, Great George Street. The Session commences annually on the second Wednesday in January, and the Meetings are continued during the second and fourth Wednesdays, until May, and resumed in November and December.

At these Meetings original communications are read, descriptive of Electrical and Telegraphic work, or of any branch connected with Electrical Science; afterwards, the merits of the communications are discussed. These papers and discussions are together with, original communications (not read before the Meetings), and abstracts and extracts of Electrical and Telegraphic science and progress, published at intervals in the form of a journal, of which every Member is entitled to receive one copy.

At these Meetings every Member, Associate, and Student has the privilege of introducing one friend.

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# Society of Telegraph Engineers.

## LIST OF

# FOREIGN MEMBERS, MEMBERS, ASSOCIATES AND STUDENTS,

*Corrected up to 1st January, 1873.*

## FOREIGN MEMBERS.

| | |
|---|---|
| Ailhaud, M. | Inspector-General of the French Telegraphs, Paris. |
| Araujo, Hippolyte | Inspector of Spanish Telegraphs, Madrid. |
| Bréguet, Alfred Niaudet | 39, Quai de l'Horloge, Paris. |
| Bréguet, M. Sen. | 39, Quai de l'Horloge, Paris. |
| Brooks, David | 22, South Twenty-First Street, Philadelphia, U.S. |
| Burton, Charles | Director-General of the Argentine Telegraphs, Buenos Ayres. |
| Capanena, Professor | Director-General of the Brazilian Telegraphs. |
| Dakers, James | Manager, Montreal Telegraph Company, Montreal, Canada. |
| D'Amico, Le Commandeur E. | Director-General of the Italian Telegraphs, Rome. |
| Frischen, Carl | 94, Margrafen Strasse, Berlin. |
| Hughes, D. E., Professor | 85, Rue Notre Dame des Champs Paris. |
| Haskins, C. H. | North Western Telegraph Company, Milwaukee, Wisconsin, U.S. |
| Lüders, H. Exc. General von | Director-General of the Imperial Russian Telegraphs, St. Petersburgh. |
| Martial, De Saint | Secretary of the International Bureau. |
| Meydam, Colonel T. | Director-General of the Imperial German Telegraphs, Berlin. |

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| Nielsen, C. . . . . | Director-General of the Norwegian Telegraphs, Christiania. |
| Orton, Hon. William . . . . | 145, Broadway, New York. |
| Pope, Frank L. . . . . | Elizabeth, New Jersey, U.S. |
| Sargent, W. D. . . . . | 814, Race Street, Philadelphia, U.S. |
| Salvatori, F. . . . . | Inspector-in-Chief of the Italian Telegraphs, Rome. |
| Siemens, Dr. Werner. . . . | Berlin. |
| Staring, M. . . . . | Director of the Netherland Telegraphs, Hague. |
| Summers, C. H. . . . . | Western Union Telegraph Company, Chicago, Illinois, U.S. |
| Tillotson, L. G. . . . . | 8, Dey Street, New York, U.S. |
| Vinchent, M. . . . . | Inspector-General of the Belgian Public Works, Brussels. |

*Total number of Foreign Members* . . 25.

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## MEMBERS.

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| ABEL, Professor, F.R.S. (*Member of Council.*) | Royal Arsenal, Woolwich. |
| Abney, W. Lieut. R.E. | Chatham. |
| Adams, W. G., Professor | Physical Laboratory, King's College, W.C. |
| Anderson, S., Capt., R.E. | British N. America (Messrs. Cox & Co., London). |
| Andrews, W. S. | 16, Telegraph Street, E.C. |
| Ansell, William T. | 66, Old Broad Street, E.C. |
| Armstrong, R. Y., Capt. R.E. | Chatham. |
| Atkinson, E., Dr., F.C.S. | 8, The Terrace, York Town, Surrey. |
| Ayrton, W. E. | India Government Telegraph Department, Calcutta. |
| Baker, Valentine, Col. 10th Hussars | 13, St. James's Place, S.W. |
| Barker, G., Lieut. R.E. | Brompton Barracks, Chatham. |
| BARLOW, WILLIAM HENRY, F.R.S. (*Member of Council.*) | 2, Old Palace Yard, S.W. |
| Bateman-Champain, Major, R.E. | 55, Parliament Street, S.W. |
| Beaumont, F., Major., R.E., M.P. | 3A, Victoria Street, Westminster, S.W. |
| Becker, Chas. | 112, St. Martin's Lane, W.C. |
| BOLTON, FRANK, Major (*Hon. Secretary.*) | 2, Westminster Chambers, Victoria Street, S. W. |
| Brasher, A. | 55, Parliament Street, S.W. |
| Bright, Sir Charles, M.I.C.E. | 50, Old Broad Street, E.C. |
| Broadbent, T. E., Lieut. R.E. | Calcutta, India. |
| Brough, S. | Calcutta, India. |
| Brown, E. O. | Royal Arsenal, Woolwich, S.E. |
| Burke, E. Haviland, M.P. | 54, Brompton Crescent, S.W. |
| Burt, J. T. | 66, Old Broad Street, City, E.C. |
| Canning, Sir Samuel, C.E. | 7, Great Winchester Street Buildings, Old Broad Street, E.C. |
| Cecil, Lord Sackville | Holwood, Beckenham, Kent. |
| Chambre, Alan E. | Camera Lodge, South Norwood, S.E. |
| Chauvin, George von | 3, Great George Street, Westminster. |
| CLARK, LATIMER, M.I.C.E. (*Vice-President.*) | 5, Westminster Chambers, Westminster, S.W. |
| Collett, Richard | 25, Burghley Road, Highgate Road, N.W. |
| COLOMB, P. H., Capt. R.N. (*Member of Council.*) | Roxeth Villa, Harrow-on-the-Hill. |

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| Cooke, Sir W. Fothergill | Branksea Lodge, Tooting, S.W. |
| Cripps, Edward | London, Brighton, and South Coast Railway, London Bridge. |
| Crocker, Henry Ring | 15, Kent Terrace, East Greenwich. |
| CULLEY, R. S., M.I.C.E. (*Vice-President.*) | Post Office Telegraphs, General Post Office. |
| Deane, Thomas | Common Side, Mitcham, Surrey. |
| Den, John D. | Cape of Good Hope Telegraph Company, 3, Moorgate Street, E.C. |
| Dorman, Mark, J. P. | Melbourne Crescent, Northampton |
| Eckford, J., Capt. R.E. | Calcutta, India. |
| Ellis, William, F.R.A.S. | Royal Observatory, Greenwich. |
| Featherstonhaugh, A., Capt., R.E. | British N. America (Messrs. Cox & Co., London). |
| Ffinch, B. T. | Calcutta, India. |
| Fitzgerald, D. G. | 6, Loughboro' Road North, Brixton, S.W. |
| Floyd, William Henry | Government Telegraph Office, Wellington, New Zealand. |
| Forde, H. C., M.I.C.E. | 6, Duke Street, Adelphi, W.C. |
| FOSTER, G. C. Professor, F.R.S. (*Member of Council.*) | 12, Hilldrop Road, N. |
| France, J. R. | 27, Amherst Road, Hackney. |
| Francis, Frank Richard | 125, New Kent Road, S.E. |
| Frasi, Frederick | 65, Brewer Street, Woolwich, S.E. |
| Galton, Douglas, Capt., C.B., F.R.S. | Chester St., Grosvenor Place, S.W. |
| Gill, W. J., Lieut. R.E. | Aldershot. |
| Gilmore, A. H., Commander R.N. | Junior Carlton Club, Pall Mall, S.W. |
| Gladstone, Dr. John Hall, F.R.S. | 17, Pembridge Square, W. |
| Glover, T. G., Col., R.E. | Burwood, Hersham, near Esher. |
| Goodeve, T. M., Professor | Goldsmith Buildings, Temple, E.C. |
| Goldstone, Charles | London and South-Western Railway, Southampton. |
| Graves, A. | North-Eastern Railway, 46, Monkgate, York. |
| Graves, E. | Postal Telegraphs, Birmingham. |
| Graves, James | Anglo-American Telegraph Company, Valentia, Ireland. |
| Gray, Matthew | 100, Cannon Street, E.C. |
| Greener, J. H. | 84, Lombard Street, E.C. |
| Greenhill, Matthew C. | Post Office Telegraphs, Belfast. |

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| Griffith, G., Master of Harrow School | Harrow. |
| Grimston, George Sylvester . . | Crane Hall, Ipswich, Suffolk. |
| Grover, George E., Capt. R.E. . . | Gore Lodge, South Kensington. |
| Hall, William Henry, Lieut. R.N. . | Byne Lodge, Stonington, Sussex. |
| Halpin, Captain Robert . . . | 38, Old Broad Street, E.C. |
| Hawkins, Frederick . . . . | Silvertown. |
| Haynes, Frederick T. Iago . . | Bristol and Exeter Railway, Taunton. |
| Henley, W. T. . . . . | Chesterton House, Plaistow, Essex. |
| Hockin, Charles . . . . | 8, Avenue Road, St. John's Wood. |
| Holmes, Nathaniel John . . . | 7, Great Winchester Street Buildings, Old Broad Street, E.C. |
| Home, R., Capt., R.E. . . | Topographical Department, War Office, New Street, Spring Gardens, S.W. |
| Hyde, H., Col. R.E. . . . . | Calcutta, India. |
| Jekyll, H., Lieut., R.E. . . . | Postal Telegraphs, London Bridge. |
| Jelf, R. H., Lieut. R.E. . . . | South Camp, Aldershot. |
| Jenkin, Fleeming, F.R.S., M.I.C.E. . | 5, Fettes Row, Edinburgh |
| Jervois, W. H., Col. R.E., C.B. . | War Office, S.W. |
| Johnson, J. Thewlis . . . . | 27, Dale Street, Manchester. |
| Lanckert, Edward . . . . | 5, Woodland Place, Charlton, S.E. |
| Lambert, M., Capt. R.E. . . . | Barbadoes (Messrs. Cox & Co., London). |
| Langdon, William . . . . | Postal Telegraphs, Southampton. |
| Laws, J. C. . . . . | Telegraph Construction and Maintenance Company, Old Broad Street, E.C. |
| Le Mesurier, T. A., Capt., R.E. . | Chatham. |
| Lendi, M. . . . . | Berne, Switzerland. |
| LINDSAY, Lord *(Vice-President)*. | 47, Brook Street, W. |
| Loeffler, Louis . . . . . | 3, Great George Street, Westminster, S.W. |
| Luke, S. P. . . . . | Calcutta, India. |
| Maitland, James M. H., Major, R.E. . | Mount Wise, Devonport. |
| MALCOLM, E. D., Major, R.E. *(Member of Council.)* . | Chatham. |
| Mallock, Capt. . . . . | 23, Harley Street, W. |
| Mitchel, Sir William . . . . | 54, Gracechurch Street, E.C. |
| Mittelhausen, Julius . . . . | 40, Upper Maryon Rd., New Charlton, S.E. |

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| Moxon, H. | Lancashire and Yorkshire Railway, Manchester. |
| Muirhead, John | 159, Camden Road Crescent, N.W. |
| Naglo, Emil. | 44, Waldemar Strasse, Berlin. |
| Newman, G. G. | London and North-Western Railway, London Road, Manchester. |
| Pepper, J. H., Professor | 209, Regent Street, W. |
| Phillips, Samuel E. | 20, Francis Terrace, Victoria Park, Hackney, N.E. |
| Phillips, Samuel E., Junior | Fern Cottage, Upper Whitworth Road, Plumstead. |
| Playfair, Dr. Lyon, C.B., LL.D., F.R.S. | 4, Queensberry Place, South Kensington, W. |
| Possmann, J. | Indo-European Telegraph Department, Persian Gulf. |
| Preece, John Richard | Ispahan, Persia, Indo-European Government Telegraphs. |
| PREECE, G. E. (*Secretary.*) | 31, Bedford Street, Covent Garden, W.C. |
| PREECE, W.H., M.I.C.E. (*Member of Council*). | Grosvenor House, Southampton. |
| Radcliffe, James | Great Northern Railway, Retford. |
| Reuter, Baron de | Kensington Palace Gardens. |
| Reynolds, Charles | Calcutta, India. |
| Ricketts, F. H. | 3, Great George Street, Westminster, S.W. |
| Robinson, D., Col., R.E. | Director-General of Indian Telegraphs, Calcutta. |
| Rokeby, Langham, Capt. | Care of Willoughby Rokeby, Esq., Admiralty, Spring Gardens. |
| Ronalds, Sir Francis, F.R.S | Battle, Sussex. |
| Rosenbusch, Edward | Mediterranean Extension Telegraph Company, Valletta, Malta. |
| SABINE, ROBERT, C.E. (*Member of Council*). | Auckland House, Willesden Lane, N.W. |
| Sach, H. | Great Eastern Railway, Shoreditch Station, E. |
| Sanger, Thomas Henry | Postal Telegraphs, Dublin. |
| Sauty, C. V. de | Eastern Submarine Telegraph Company, Gibraltar. |
| Saunders, John Brewer | The Laurels, Taunton. |
| Schwendler, L., C.E. | India Government Telegraphs, Calcutta, India. |
| Scott, R. G., Lieutenant R.E. | Chatham. |

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| SCUDAMORE, FRANK IVES, C.B. *(President.)* | General Post Office, St. Martin's-le-Grand, E.C. |
| Shaw, W. H. . . . . | Post Office Telegraphs, Newark, Notts. |
| SIEMENS, CARL, M.I.C.E. . . *(Member of Council.)* | 3, Great George Street, Westminster, S.W. |
| SIEMENS, CHARLES WILLIAM F.R.S., D.C.L. *(Past President.)* | 3, Great George Street, Westminster, S.W. |
| Silver, S. W. . . . . | 67, Cornhill, E.C. |
| Simmons, Sir Lintorn, Major-Gen., K.C.B. | Royal Military Academy, Woolwich. |
| Smith, Theophilus . . . . | 6, Merrick Square, Borough, S.E. |
| Smith, Willoughby . . . . | 18, Wharf Road, City Road, N. |
| Spagnoletti, C. E. . . . . | G. W. Railway, Paddington, W. |
| Sprot, J. Lieut.-Col. . . . . | Junior United Service Club, Waterloo Place. |
| Stockley, Major, R.E. . . . | Chatham. |
| STOTHERD, R. H., COLONEL, R.E. *(Member of Council.)* | Chatham. |
| Tansley, Edward . . . . | Postal Telegraphs, Edinburgh. |
| Taylor, Herbert . . . . . | The Avenue, Gipsy Hill, S.E. |
| Ternant, A. L. . . . . | Algiers and Malta Telegraph Co., Marseilles, France. |
| THOMSON, SIR WILLIAM, F.R.S. LL.D. *(Vice-President)* | The University, Glasgow, N.B. |
| Tietgen, C. F. . . . . | Great Northern Telegraph Company, Copenhagen. |
| Todd, Lieut. R.E. . . . . | Chatham. |
| Turner, Captain H. T., R.E. . . | Post Office Telegraphs, Ipswich. |
| Tyndall, John, Professor, LL.D., F.R.S. | Royal Institution, Albemarle St., W. |
| VARLEY, C. F., M.I.C.E., F.R.S. . *(Member of Council.)* | 1, Great Winchester Street Buildings, Old Broad Street, E.C. |
| Varley, F. H. . . . . | Mildmay Park Works, Stoke Newington, N. |
| Varley, S. A. . . . . | 66, Roman Road, Holloway, N. |
| Walker, C. V., F.R.S. . . . | Fern Side, Red Hill, Reigate. |
| Walker, E. J. Douglas . . . | 19, Euston Square. |
| Walsh, John . . . . . | Postal Telegraph Department, Manchester. |
| Warren, T. T. P. B. . . . . | Tamworth House, Mitcham, Surrey. |
| Weaver, Henry . . . . . | 1, Albert Square, Clapham Road, S.W. |
| Webb, F. C., M.I.C.E. . . . | 57, Maitland Park Road, N.W. |

| | |
|---|---|
| **WEBBER, C. EDMOND, MAJOR, R.E.** (*Member of Council.*) | Postal Telegraphs, 101, Cannon Street, E.C. |
| Wheatstone, Sir Charles, D.C.L., F.R.S. | 19, Park Crescent, Portland Place, N.W. |
| **WHITEHOUSE, E. O. WILDMAN,** (*Member of Council.*) | Pilgrim Lane, Hampstead, N.W. |
| Williamson, Prof. . . . . | University College, Gower Street, W.C. |
| Wilson, H. Schütz. . . . . | 185, Regent Street, W. |
| Winter, G. K., F.R.A.S. . . . | Arconum, near Madras. |
| Winter, William Henry . . . | Postal Telegraph Department, General Post Office. |

*Total number of Members* . . . 155

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## ASSOCIATES.

| | |
|---|---|
| Aird, Junr., John | Southwark. |
| Andrews, Thomas | French Atlantic Telegraph Company, Brest, France. |
| Arnold, George | Post Office Telegraphs, Telegraph Street, E.C. |
| Arnold, John | Post Office Telegraphs, Telegraph Street, E.C. |
| Ashton, Edwin | Postal Telegraphs, Camden Town-N.W. |
| Aylmer, John, C.E. | 18, Great George Street, Westminster, S.W. |
| Bailey, John | India Rubber Co., Silvertown, E. |
| Bain, Alexander | |
| Banker, S. M. | Post Office Telegraphs, Telegraph Street, E.C. |
| Barrow, Capt. Robert Knapp | 80, Cornhill. |
| Beckett, J. W. | Posta Telegraphs, Lancaster. |
| Beckinsole, Edgar William | 23, Langley Street, Newport, Isle of Wight. |
| Bell, Andrew | Postal Telegraphs, Gloucester Rd., N.W. |
| Bell, Alexander Carlyle | 7, Great Winchester Street Buildings, E.C. |
| Bent, William | 6, Duke Street, Adelphi, W.C. |
| Betts, James A. | Post Office Telegraphs, Oxford. |
| Biddulph, W. W. | Care of Messrs. Grindlay & Co., 55, Parliament Street. |
| Black, Francis Daniel | Postal Telegraphs, Waterford. |
| Blewett, George | Postal Telegraphs, Oxford. |
| BLUNDELL, J. W. (*Auditor.*) | 16, Gresham Street, E.C. |
| Bohr, Heinrick | Great Northern Telegraph Company, Amoy, China. |
| BOTTOMLEY, J. T. (*Member of Council.*) | The College, Glasgow, N.B. |
| Bottomley, William | 3, Collyer's Buildings, Blackheath Hill. |
| BORDEAUX, JOHN (*Member of Council.*) | Submarine Telegraph Company, Dover |
| Brown, R. T. | French Atlantic Telegraph Company, Duxbury, Mass., U.S. |
| Burke, J. | Indian Government Telegraph. |
| Campbell, Henry | 9, Hammer's Terrace, Greenwich, S.E. |
| Carlile, Frank W. | Post Office Telegraphs, Plymouth. |
| Carr, George M. | Postal Telegraphs, Sunderland. |

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| Cawood, Reuben | Postal Telegraphs, Glasgow, N.B. |
| Chambers, John Charles | Postal Telegraphs, Stockton-on-Tees. |
| Chambre, Charles F. | Manor Cottage, Putney. |
| Chandler, Robert Harvey | 106A, Jermyn Street, S.W. |
| Clapp, W. H. | 14A, Austin Friars, E.C. |
| Collings, Charles E. | Postal Telegraphs, Plymouth. |
| Collins, Lawrence | Post Office Telegraph, 88, South Mall, Cork. |
| Comport, George Henry | Postal Telegraphs, Nottingham. |
| Cooksley, W. | Postal Telegraphs, Bristol. |
| Cordeaux, John Henry | Postal Telegraphs, Birmingham. |
| Corner, C. R. | Porthcurnow, Penzance, Cornwall. |
| Cromartie, Duncan | Indian Government Telegraphs, Calcutta. |
| Crampton, T. Russell, M.I.C.E. | 12, Great George Street, S.W. |
| Crossley, Louis J. | Moorside, Halifax, Yorkshire. |
| Cunbill, Frank W. | Postal Telegraphs, Plymouth. |
| Dallas, John | 17, Park Street, Greenwich, S.E. |
| Daniell, Francis T. Bristow | Indo-European Government Telegraphs, 55, Parliament Street, S.W. |
| DANVERS, F. C. (*Auditor.*) | India Office, S.W. |
| Delany, Patrick | Post Office Telegraphs, 52, Ranelagh Road, Dublin. |
| Denmead, Thomas | Postal Telegraphs, Exeter. |
| Dixon, G. H. | Post Office Telegraphs, Telegraph Street. |
| Doherty, John | Postal Telegraphs, Manchester. |
| Donovan, H.C. | 44, New Manor Road, New Cross, S.E. |
| Dorman, Thomas | Postal Telegraphs, Stockton-on-Tees. |
| Dunn, Andrew S. | Telegraph Department, Caledonian Railway Co., Glasgow, N.B. |
| Drury, Sen., William | Postal Telegraph Service, Gloucester Road, N.W. |
| Edwards, J. R. | Postal Telegraphs, Chester. |
| Eggington, Alfred | Suza Modica Telegraph, Florence, Italy. |
| ERICHSEN, H. G. (*Member of Council.*) | 7, Gt. Winchester Street Buildings, E.C. |
| Evans, Frederick E. | Postal Telegraphs, Birmingham. |
| Falck, A. | Gt. Northern Telegraph Company, Aberdeen, N.B. |

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|---|---|
| Field, George | Postal Telegraphs, Old Steine, Brighton. |
| Fischer, Henry | Postal Telegraphs, Telegraph St. E.C. |
| Fisher, Henry F. | British Indian Extension Telegraph Company, Singapore. |
| Fleetwood, Charles Thomas | Post Office Telegraphs, Telegraph Street, E.C. |
| Fletcher, John William | London and North-Western Railway Telegraph Department, Chester. |
| Fletcher, Thomas | Hooper's Telegraph Works, Millwall, E. |
| Flewell, A. | Postal Telegraphs, Bristol. |
| Foster, Arthur Le Neve | East Hill, Wandsworth, S.W. |
| Gavey, John | Postal Telegraphs, Bristol. |
| Gibson, James | Postal Telegraphs, Edinburgh. |
| Gordon. C. B. P. | Indian Government Telegraphs. |
| Gott, John | French Atlantic Telegraph Company, St. Pierre, Newfoundland. |
| Granville, William P. | 28, Hanover Street, Islington, N. |
| Grant John | 26, Old Broad Street, E.C. |
| Guenzel, Ernst | 9, Upper Woodland Terrace, New Charlton, S.E. |
| Hall, Walter | 21, Aldermanbury. |
| Harborow, Henry | 4, Circus Street, Marylebone, W. |
| Hargreaves, J. W. | Postal Telegraphs, Carlisle. |
| Heaviside, A. W. | Postal Telegraphs, Newcastle-on-Tyne. |
| Henley, George | 47, Essex Street, Islington, N. |
| Higgs, Richard, M.A. | Boy Court, Ludgate Hill, E.C. |
| Hill, Joseph Tripp | Post Office Telegraphs, Telegraph Street, E.C. |
| Hill, Thomas | Post Office Telegraphs, Telegraph Street, E.C. |
| Hoeltzer, Charles | 3, Gt. George Street, Westminster. |
| Horner, Albert B. | General Post Office, St. Martin's-le-Grand. |
| Hookey, James | Postal Telegraphs, General Post Office, E.C. |
| Humble, George | Postal Telegraphs, Newcastle-on-Tyne. |
| Humphries, William | Post Office Telegraphs, Limerick. |
| Hurley, Edward Butler | India Telegraph Department, Colombo, Ceylon. |
| Irminger, Frederick | Great Northern Telegraph Company, Hong-Kong, China. |

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|---|---|
| James, F. R. | Government Telegraph Department, Melbourne, Australia. |
| Jenkin, John | Postal Telegraphs, Newark, Notts. |
| Jobson, Howard C. | Dudley. |
| Joel, H. F. | 172, Great Portland Street W. |
| Johnstone, W. P. | Indian Government Telegraphs. |
| Jones, John Rymer | Truro House, Westbourne Park, W. |
| Kempe, H. R. | Postal Telegraphs, Southampton. |
| Kerry, C. H. | Postal Telegraphs, Bristol. |
| Knight, John Henry | Postal Telegraphs, Doncaster. |
| Lee, Robert | Riband Post Manufactory, New Islington, Manchester. |
| Lemon, C. | Wellington, New Zealand. |
| Lessels, David | Postal Telegraphs, Edinburgh. |
| Lloyd, William | Whitehall Club, Parliament Street, S.W. |
| London, Robert | 10, Vanburgh Road, East Greenwich, S.E. |
| Lowe, Thomas | 8, Great Winchester Street Buildings, E.C. |
| Lusty, J. W. | Postal Telegraphs, Exeter. |
| Mackenzie, A. C., Lieut., R.E. | Folkestone. |
| Mackie, S. J. | 84, Kensington Palace Road, Bayswater, W. |
| Maclachlan, | Post Office Telegraphs, Telegraph Street, E.C. |
| McLean, James | 2, Ovington Square, S.W. |
| McIntyre, John | Postal Telegraphs, Inverness. |
| Michel, Francisque | 60, Rue St. André des Arts, Paris. |
| Möll, Frederick H. L. R. | Indo-European Telegraph Company, 16, Telegraph Street, E.C. |
| Morgan, Charles Amis | Post Office Telegraphs, Telegraph-Street, E.C. |
| Morris, C. | Care of Major Webber. |
| Morrison, G. James | Engineer's Office, Clifton Extension Railway, Bristol. |
| Muirhead, Alexander, D.Sc., F.C.S. | 159, Camden Road Crescent, N.W. |
| Mygind, John | Newcastle-on-Tyne. |
| Munro, John | Hoopers's Telegraph Works. Millwall, E. |
| Naylor, J. E. | Postal Telegraphs, York. |
| Neale, John | North Staffordshire Railway, Stoke-on-Trent. |
| Noble, Martin | Postal Telegraphs, Lancaster. |
| Ollard, J. F. | Lloyd's, Royal Exchange, E.C. |

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|---|---|
| Ormiston, Frederick Aldridge . . | Postal Telegraphs, General Post Office, E.C. |
| Partridge, G. Noble . . . . | Postal Telegraphs, Exeter. |
| Patten, Frederick A. . . . . | Indo-European Government Telegraphs, 55, Parliament Street, S.W. |
| Petersen, K. . . . . | 7, Great Winchester Street Buildings, E.C. |
| Pinchin, William Henry . . . | Postal Telegraphs, Exeter. |
| Pomeroy, Henry . . . . | Post Office Telegraphs, Mullingar. |
| Radcliffe, Arthur . . . . | 7, Union Street, Birmingham. |
| Ramsay, John, Lieut. R.E. . . | Post Office Telegraph, London Bridge, S.E. |
| Reid, Frank . . . . . | Postal Telegraphs, Newcastle-on-Tyne |
| Richardson, H. . . . . | Postal Telegraphs, Douglas, Isle of Man. |
| Risch, Gustav . . . . . | 9, Armstrong Terrace, New Charlton, S.E. |
| Ritso, F. C. G. . . . . | 7, Lothbury, E.C. |
| Robertson, J. . . . . | Postal Telegraphs, Bristol. |
| Rolls, Edward T. . . . . | L. & S. W. Railway, Southampton |
| Russell, Frank . . . . | 2, Talbot Court. Gracechurch St. |
| Saunders, H. . . . . | British Indian Submarine Telegraph Company, 66, Old Broad Street. |
| Sax, J. . . . . | 108, Great Russell Street, W.C. |
| Schramm, Otto . . . . | 3, Gt. George Street, Westminster, S.W. |
| Shaw, John . . . . . | Postal Telegraphs, Bolton. |
| Shaw, Captain W. . . . . | 73rd Regiment, 52, Hans Place, S.W. |
| Siemens, Alexander . . . . . | 3, Gt. George Street, Westminster, S.W. |
| Sivewright, James . . . . | Postal Telegraphs, Southampton. |
| Smith, Toulmin . . . . . | 3, Gt. George Street, Westminster, S.W. |
| Smith, J. H. . . . . | 2, Westminster Chambers. |
| Spagnoletti, Hylton . . . . | 4, Circus Street, Marylebone, W. |
| Stevenson, Ed. Alf. . . . . | Telegraph Construction and Maintenance Company, Enderby's Wharf, East Greenwich, S.E. |
| Stokes, John Scott . . . . | Postal Telegraphs, Southampton. |
| Symington, Robert Stevenson . | Postal Telegraphs, Glasgow. |
| Stevenson, George . . . . | Eastern Sub-Marine Telegraph Company, Alexandria, Egypt. |

| | |
|---|---|
| Tansley, William | Post Office Telegraphs, Portarlington. |
| Tarbutt, P. F. | The Avenue, Streatham. |
| Taylor, William Grigor | Telegraph Construction Company, Morden Wharf, East Greenwich. |
| Teale, Frederick G. | Indian Government Telegraphs, care of Grindlay & Co., 55, Parliament Street, S.W. |
| Theiler, M. | 156, Barnsbury Road, N. |
| Thompson, H. E. | Indian Government Telegraphs, Alipore. |
| Tolmé, Julian H., M.I.C.E. | 1, Victoria Street, Westminster, S.W. |
| Truman, Edwin Thomas | 23, Old Burlington Street, W. |
| Treuenfeld, G. V. Fischer | 3, Great George Street, Westminster. |
| Tubb, Albert | Postal Telegraphs, Southampton. |
| Tyler, W. J. | 100, Cannon Street. |
| Walton, John | Postal Telegraphs, Birmingham. |
| Watkins, Lieut. R.E. | Gibraltar. |
| Watson, C., Lieut. R.E. | Chatham. |
| Werdermann, E. H. | 4, Princes Street, Stamford Street, Southwark, S E. |
| Willmot, Joseph | Postal Telegraphs, General Post Office. |
| Winter, Charles | Postal Telegraphs, Guernsey. |
| Woollen, C.H. | Postal Telegraphs, Exeter. |

*Total Number of Associates* . . . . 170

## STUDENTS.

| | |
|---|---|
| Graham, William John | Henley's Works, North Woolwich, E. |
| Palliser, Edward | 2, Westminster Chambers, S.W. |

*Total number of Students* . . . 2

## TOTAL NUMBER OF MEMBERS.

| | |
|---|---|
| Foreign Members | 25 |
| Members | 155 |
| Associates | 170 |
| Students | 2 |
| Total | 352 |

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# Supplemental List of Members.

*To April* 9, 1873.

## HONORARY MEMBERS.

| | |
|---|---|
| Sir George Biddel Airy K.C.B., *Astronomer Royal.* | Greenwich. |
| Gen. Sir Edward Sabine, K.C.B., R.A., | 13, Ashley Place, Victoria Street, S.W. |
| Professor William Weber, F.A.S. | Gottingen. |

## FOREIGN MEMBERS.

| | |
|---|---|
| Aguayo, Don Waldo | Santiago, Chili. |
| Alteneck, F. Von Hefner | 90, Markgrafenstrasse, Berlin. |
| Calahan, E. A. | 17, Cornhill, E.C. |
| Eckert, Gen. Thomas | New York, U.S. |
| Field, Cyrus | New York, U.S. |
| Lasard, Dr. Ad. | 6, Hohenzollern Strasse, Berlin |
| Madsen, C. L. | Great Northern Telegraph Company, Copenhagen. |
| Pias, Don Ramon | Santiago, Chili. |
| Prescott, George | New York, U.S. |
| Repsold, J. G. | Rio Janeiro, Brazil. |
| Torres, Don Diego | Santiago, Chili. |
| Ugarto, Don A. V. | Santiago, Chili. |
| Zetzsche, Dr. K. E. | Chemnitz, Saxony. |

## MEMBERS.

| | |
|---|---|
| Ashurst, W. H. | General Post Office, E.C. |
| Bristow, G. L. | 1, Copthall Buildings, E.C. |
| Danvers, Juland | India Office, S.W. |
| Clark, Edwin, M.I.C.E. | 5, Westminster Chambers, S.W. |
| Douglas, Col. | East Indian United Service Club, 14, St. James's Square, S.W. |
| Evans, Mortimer | West Regent Street, Glasgow. |
| Fuller, Thomas | 119, Glo'ster Terrace, Hyde Park. |
| Gutteries, J. | Kingston, Jamaica. |

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|---|---|
| Hooper, J. P. | "The Hut," Mitcham. |
| Lambert, Frank | 15, Great Castle Street, Regent' Circus. |
| Maxwell, Professor Clerk, F.R.S. | Cambridge. |
| Moncrieff, Major Alexander | Athenæum Club, S.W. |
| Saward, George | 66, Old Broad Street, E.C. |
| Schaw, Lieut-Col. Henry, R.E. | Staff College, Farnboro Station. |

## ASSOCIATES.

| | |
|---|---|
| Adams, A. I. S. | Post Office Telegraphs, Telegraph Street, E.C. |
| Adamson, E. W. | Submarine Telegraph Company, Eastdean, Eastbourne. |
| Angell, Thomas | Buckingham Gate. S.W. |
| Allen, J. J. | Indian Government Telegraphs, Calcutta. |
| Ascough, T. B. | Postal Telegraphs, 101, Cannon Street, E.C. |
| Bayley, E. W. | Postal Telegraphs, Hull. |
| Bazeley, Thomas | Postal Telegraphs, Cardiff. |
| Belchamber, W. | Postal Telegraphs, Cardiff. |
| Benest, Henry | India-Rubber Company, Silvertown. |
| Betts, A. S. | Kurrachee. |
| Bewick, T. J., C.E. | 2, Westminster Chambers, S.W. |
| Blissett, T. | Calcutta. |
| Boteler, R. | Indo-European Telegraph, Calcutta. |
| Bullivant, W. M. | 114, Fenchurch Street, E.C. |
| Bulmer, J. A. | Postal Telegraphs, Hull. |
| Cheesman, H. G. | Postal Telegraphs, Hull. |
| Collins, A. | 4, Queen's Square, Westminster, S.W. |
| Cook, E. E. | 101, Cannon Street, E.C. |
| Cox, H. J. | 48, Arthur Road, Holloway, N. |
| Crace, H. Win | 31, Lombard Street, E.C. |
| Cross, P. W. | Postal Telegraphs, Cardiff. |

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Davies, William Henry . . . 17, Cornhill, E.C.
Durran, William . . . . Eastern Telegraph Company, Alexandria.

Elliott, Thomas . . . . . Postal Telegraphs, Basingstoke.

Fahie, J. J. . . . . Indo-European Telegraphs, Jask.
Fisher, Commander J. A., R.N. . H.M.S. "Excellent," Portsmouth.
Fleming, J. C. . . . . Perth, Western Australia.
Fraser, Charles . . . . . 24, City Road.
Frost, Alfred J. . . . . 5, Westminster Chambers, S.W.

Gamble, D. P. . 6, Coleberne Road, South Kensington.
Groves, William . . . . 172, Great Portland Street, W.

Hall, John . . . . . Postal Tel graphs, Manchester.
Hamilton, F. A. . . . . Morden Wharf, East Greenwich.
Hancock, Walter . . . . 10, Upper Chadwell Street, Myddleton Square.
Haynes, J. . . . . Postal Telegraphs, Gloucester.
Hewett, Commander D. R., R.N. . 22, Arundel Street, Strand, W.C.
Higgins, Frederick . . . . Exchange Telegraph Company, 17, Cornhill, E.C.

Isherwood, Fred. . . . . 101, Cannon Street, E.C.

Jones, T. E. . . . . 24, City Road.
Jones, J. C. D. . . . . British Indian Extension Telegraph, Singapore.
James, Sidney . . . . . Postal Telegraphs, Telegraph Street, E.C.
Johnson, William . . . . Postal Telegraphs, 67, Portland Crescent, Leeds.

Kaarsberg, Sofus . . . . 7, Great Winchester Street Buildings, E.C.
King, W. F. . . . . Hooper's Telegraph Works, Mitcham.

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| | |
|---|---|
| Laister, James | 101, Cannon Street, E.C. |
| Lucas, F. R. | 3, Glen Mohr Terrace, Hyde Vale, Greenwich. |
| Mackie, Alex. | "Guardian" Office, Warrington. Lancashire. |
| Mance, Henry | Indo-European Government Telegraph, Kurrachee. |
| May, Joseph | 2, Trinity College, Church Street, East Greenwich. |
| Newsam, Thomas | Eastern Telegraph Company, Alexandria. |
| Nind, L. L. | Postal Telegraphs, Newcastle-on Tyne. |
| Oakshot, A. | Postal Telegraphs, Southampton. |
| Payter, J. W. | Telegraph Department, Melbourne, Victoria. |
| Parmiter, Albert | Postal Telegraphs, Reading. |
| Parker, J. | St. Thomas', West Indies. |
| Riddle, G. H. | Telegraph Account Branch, General Post Office, E.C. |
| Rowe, Thomas | Postal Telegraphs, Manchester. |
| Steet, G. C., F.R.C.S. | Melbourne House, Rosslyn Hill, Hampstead. |
| Sale, Lieut., R.E. | Chatham. |
| Sheath, Alfred | Auckland, New Zealand. |
| Shepherd, F. | Postal Telegraphs, Brighton. |
| Smythe, John | Valentia, Ireland. |
| Taplin, Charles | Postal Telegraphs, Cardiff. |
| Ticehurst, F. G. | Battle, Sussex. |
| Trenan, Edwin | Postal Telegraphs, Leeds. |
| Tubb, W. H. | India Government Telegraphs, Indore, Central India. |

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|---|---|
| Uren, John George | Postal Telegraphs, Penzance. |
| Verney, Comr. | 22, Arundel Street, Strand, W.C. |
| Vyle, Samuel | Postal Telegraphs, Glasgow. |
| Weatherall, T. E. | Telegraph Construction and Maintenance Company, Greenwich. |
| West, George | Eastern Submarine Telegraph Company, Alexandria. |

## STUDENTS.

| | |
|---|---|
| Gatehouse, Thomas | 172, Great Portland Street, W. |
| Hooper, Samuel | Tremerton House, Clapham Park. |
| Hayes, Alfreed | 2, Westminster Chambers. |

## TOTAL NUMBER OF MEMBERS.

| | |
|---|---|
| Honorary Members | 8 |
| Foreign Members | 38 |
| Members | 169 |
| Associates | 241 |
| Students | 5 |
| TOTAL | 456 |

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